"The Life Satisfaction Approach to Valuing Public Goods.
Theoretical Discussion and Empirical Applications
to Air Pollution, Flood Disasters and Terrorism"

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The Faculty of Economics, Business Administration and Information Technology of the University of Zurich hereby authorises the printing of this Doctoral Thesis, without thereby giving any opinion on the views contained therein.

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The Dean: Prof. Dr. H. P. Wehrli

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## Abbreviations

| | |
|---|---|
| AD | Action Directe |
| CAV | Comité d'Action Viticole |
| CLODO | Comité Liquidant ou Détournant les Ordinateurs |
| CPI | Consumer price index |
| CRED | Centre for Research on the Epidemiology of Disasters |
| CS | Compensating surplus |
| CV | Contingent valuation |
| DIW | Deutsches Institut für Wirtschaftsforschung |
| DRM | Day reconstruction method |
| EB | Euro-Barometer Survey Series |
| EEG | Electro-encephalography |
| EF | Emission factor |
| EMA | Ecological momentary assessment |
| EM-DAT | Emergency disasters database of CREED |
| EPA | U.S. Environmental Protection Agency |
| ESM | Experienced sampling method |
| ETA | Euskadi Ta Askatasuna |
| FEMA | U.S. Federal Emergency Management Agency |
| FLNC | Front de Libération Nationale de la Corse |
| fMRI | functional magnetic resonance imaging |
| FRG | Federal Republic of Germany |
| GDP | Gross domestic product |
| GDR | German Democratic Republic |
| GIA | Groupe Islamic Armée |
| GIS | Geographic information system |
| GSOEP | German Socio-Economic Panel |
| GSS | U.S. General Social Survey |
| HEL | Light fuel oil |
| HH | Household |
| HS | Heavy fuel oil |
| INLA | Irish National Liberation Army |

| | |
|---|---|
| IRA | Irish Republican Army |
| IV | Instrumental variable |
| LR | Likelihood ratio |
| MWTP | Marginal willingness-to-pay |
| NFI | National Flood Insurance |
| NFIP | National Flood Insurance Program |
| $NO_2$ | Nitrogen dioxide |
| NUTS | Nomenclature des unités territoriales statistiques |
| OECD | Organisation for Economic Co-operation and Development |
| OLS | Ordinary least squares |
| OMB | Office of Management and Budget |
| PANAS | Positive and Negative Affect Schedule |
| PET | Positron emission topography |
| PIRA | Provisional Irish Republican Army |
| PSNI-data | Security statistics of the Police Service of Northern Ireland |
| RAF | Rote Armee Fraktion |
| RAND-data | RAND-St. Andrews Chronology of International Terrorism |
| SAS | Special Air Service |
| $SO_2$ | Sulfur dioxide |
| $SO_x$ | Sulfur oxides |
| SWLS | Satisfaction with Life Scale |
| TSP | Total suspended particulates |
| TWEED-data | Terrorism in Western Europe: Event data |
| UBA | Umweltbundesamt (German federal environmental agency) |
| UDA | Ulster Defence Association |
| ULF | Loyalist Volunteer Force |
| UVF | Ulster Volunteer Force |
| WTP | Willingness-to-pay |

## Preface

This thesis is based on my research undertaken at the Institute for Empirical Research in Economics at the University of Zurich. First and foremost, I want to thank my mentor Prof. Dr. Dr. h.c. mult. Bruno S. Frey. He has challenged and inspired me to analyze the world from an economic perspective while always being open to insights from other social sciences. Chapter 5 on the effect of terrorism on life satisfaction probably best represents this broad understanding of economics. While only a few economists dare to avoid beaten tracks and apply the economic approach to topics such as terrorism, and even fewer economists dare to break the taboo of using subjective well-being data, he suggested to simultaneously defy both conventions. He has always been very supportive and many ideas reflected in this book were developed in numerous discussions. At the same time, he has always given me the freedom to pursue my own ideas. He has also created an atmosphere within his research group from which I greatly benefited. Many conversations with Christine Benesch, Dr. Matthias Benz, Silke Humbert, Reto Jegen, Dr. Stephan Meier, Susanne Neckermann, Dina Pomeranz and Prof. Dr. Alois Stutzer have influenced my thinking and the content of this thesis.

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## 1. Introduction

Early economists and utilitarians such as Jeremy Bentham (e.g. 1789[1907]) and Francis Ysidro Edgeworth (e.g. 1881) were convinced that utility is – at least in principle – measurable. In their view, the concept of utility thus allows society to put government action – from judicial and legal reform to distribution of wealth and labor – on a rational footing. The "ordinalist revolution" in economics in the 1930s led by Lionel Robbins (e.g. 1932), abandoned any substantive and measurable idea of utility. Hicks and Allen (1934) showed that price theory can dispense with a cardinal utility concept and Samuelson (1938) formulated the behaviorist concept of utility as preferences summarizing choice – the concept of "revealed preference", which is now standard in economics (see Stigler 1950; Cooter and Rappoport 1984; Frey and Stutzer 2002a; Colander 2007).

This fixation on observable market behavior deprives economics of its ability to contribute to many important policy issues. One of these policy issues that will take center stage in what follows is the valuation of public and publicly provided goods. While market prices reflect the value of marketed goods to the marginal consumer and guide scarce resources to their most valuable use, market forces cannot be relied on to reveal prices that reflect the true social value of public or publicly provided goods. Because individuals have no incentive to disclose their true demand for non-excludable goods, for long, economists have been very pessimistic as to whether it is possible to assess people's preferences for public goods. This pessimism is exemplified by the following statement: "[T]he very essence of public goods problem is that there is no way these preferences can be determined" (Due and Friedlaender 1973, p. 53; similar skepticism is expressed by Eckstein 1958; Fisher and Peterson 1976).

A failure of economists to take part in the debate on the value of public goods would be especially severe in light of the increasing importance of these goods. In most countries, government spending soared. In percent of GDP, it increased from 11% in 1870 to 46% in 1996 in a sample of 17 OECD countries (Tanzi and Schuknecht 2000, table 1.1). Not all of this spending finances public goods and many public goods will be provided through regulation rather than spending. Nevertheless, the figures suggest that the supply of publicly provided goods did increase. Further, it is highly likely that demand too increased as public goods typically have high income elasticities (e.g. Costa, D. L. and Kahn 2003 on mortality risk).

Fortunately, economists have overcome both the self-restriction and the resulting difficulties. Non-market valuation is now a firmly established field in economics. A vast literature exists, reflecting extensive research and considerable progress in valuing public goods. Economists have developed non-market valuation techniques that do not require direct measures of utility. Essentially, two avenues have been pursued: revealed preference methods on the one hand and stated preference methods on the other hand. The former are based on actual behavior and utilize complementary and substitutive relationships between public and various marketed goods to infer the value attributed to public goods from market transactions in private goods. In the case of stated preference methods, individuals are directly asked to value the public good in question; the most prevalent method is contingent valuation. However, despite their ingenuity, most of the approaches have serious flaws. A much more recent development or, more aptly, "revolution" (Frey et al. 2008) in economics is the use of subjective well-being data. In happiness research in economics it is the common understanding that subjective well-being is a suitable approximation to individual utility. Thus, researchers in the field of happiness research revived the concept of utility as a measurable quantity.

This thesis aims at connecting these two largely separate strands of literature and at rendering data on subjective well-being useful for the valuation of public goods. Specifically, it presents the *life satisfaction approach* to valuing of public goods. With the life satisfaction approach, subjective well-being is regressed on the public good of interest, income and other covariates. Using the coefficients for the public good and income, it is possible to calculate utility constant trade-off ratios between the public good and income for marginal and inframarginal changes in the public good provision. In addition to discussing conceptual issues, we apply the life satisfaction approach to estimate the utility losses caused by air pollution, flood disasters and terrorism. These three public bads have been, are and will be top priorities in the public debate and the political process for a long time.

Air pollution belongs to the long-standing environmental concerns. It has been addressed by some of the earliest and most significant environmental regulations ever enacted. As a consequence, air quality has considerably improved in many countries. An example is the development of sulfur dioxide ($SO_2$) in Germany between 1985 and 2003 documented in chapter 3. The situation is less favorable in other countries and for other pollutants. In developing countries, premature deaths from pollution-related illnesses are still legion (e.g. Economist 2007b).

But also in developed countries, air pollution makes time and again headline. For example, in early 2007 in the United Kingdom, high concentrations of particulate pollution and nitrogen dioxide ($NO_2$) prompted alarmist headlines by newspapers: "Britain's dirty cities more dangerous than an A-bomb" (The Independent 2007, p. 14). In the policy arena, greenhouse-gases currently receive the most attention. Even more prevalent in the media than air pollution are natural disasters and terrorism. As witnessed by the surprising re-election of the German chancellor Gerhard Schroeder after the flood disaster in eastern Germany and the sudden and substantial drop in votes going to the reigning Partido Popular after the Madrid bombings in 2004, incidents of floods and terrorism as well has their handling can have considerable political impacts. Moreover, the threat is increasing. Global warming-induced changes in precipitation and run-off patterns as well as rising sea levels will increase the risk of floods. Terrorism remains an ever-present danger though its face is changing. In Europe, the conflicts from the heyday of European terrorism are largely settled: Most left-wing terrorist groups have ceased to exist and the Spanish ETA is only a pale version of the terrifying terrorist group it once was. In Northern Ireland, the peace process has drastically reduced the bloodshed and the power sharing agreement between Sin Fein and Paisley's Democratic Unionist Party gives hope that peace will endure. At the same time, however, the threat of Islamic terrorism is increasing worldwide (Economist 2007c).

The remainder of this thesis is organized in five chapters. Chapter 2 introduces the general idea of using subjective well-being data to value public goods. The basics of the life satisfaction approach can be explained briefly because the underlying ideas are simple. As the approach stands and falls with the quality of subjective well-being data, we devote a longer discussion to measurement issues and data requirements. In order to highlight the strengths of the life satisfaction approach, we compare it to the standard approaches for the valuation of public goods. Further, we discuss several identification issues and present a review of previous applications. Chapters 3 to 5 contain the own applications. In chapter 3, we use the life satisfaction approach to value air quality. The estimates are based on individual-level panel and high-resolution $SO_2$ data for Germany in the years 1985 to 2003. To avoid simultaneity problems inherent in estimating the effects of pollution, we construct a novel instrument exploiting the natural experiment created by the mandated scrubber installation at power plants, with wind directions dividing counties into treatment and control groups. The estimates based on the life

satisfaction approach are complemented with estimates based on hedonic housing regressions. Chapter 4 applies the life satisfaction approach to assess and monetize utility losses caused by flood disasters in 17 OECD countries between 1973 and 2004. We compare our estimates to price discounts found in U.S. housing markets for houses located in floodplains. Moreover, in an exploratory analysis, we estimate the mitigating effects of different risk transfer mechanisms. In chapter 5, we use the approach to assess the overall social costs of terrorism. We estimate the consequences for the individuals affected by terrorist activities in France, the Republic of Ireland and the United Kingdom in the years 1973 to 2002. France is the Western European country with the highest number of recorded international terrorist incidents in the last quarter of the twentieth century and the Northern Ireland conflict is, beyond doubt, one of the most violent conflicts in Europe's recent history. Chapter 6 draws conclusions for two research areas in economics – happiness research and non-market valuation – and policy. To avoid giving naïve policy recommendations, we shortly discuss from a politico-economic perspective the role benefit estimates can play in the political process. Finally, the chapter also suggests directions for future research.

## 2. The life satisfaction approach to value public goods

### 2.1 The basic concept

The life satisfaction approach is grounded in the recent revolution in economics that has enriched anew the concept of utility with psychological or hedonic content. In mainstream economics, the concept of utility is completely devoid of any such elements. The concept of utility has thus come to carry two quite distinct meanings. Following the terminology proposed by Kahneman and Varey (1991) and Kahneman, Wakker and Sarin (1997) one can distinguish between the concepts of experience and decision utility.

The notion of decision utility refers to the utility concept in mainstream economics. Decision utility is given a technical definition as that which is maximized in consistent choice. It is a representation of preferences which are simply choice-connected rankings of outcomes. The axiomatic approach holds that the choices made by individuals provide all the information required to infer the utility of outcomes. Subjectivist experience as captured by surveys is rejected as being not objectively observable and therefore "unscientific". However, this position restricts the questions that can be addressed. It is, for example, not possible to discriminate between competing theories that predict the same patterns of behavior, but differ in what they put forward as people's utility level (Frey and Stutzer 2005b). Moreover, conceptions about individuals' preferences or utility functions remain vague and the valuation of public goods is hampered (Arrow 1958, pp. 8-9; Schelling 1968, pp. 143-144). Revealed preference methods cannot be applied in all cases of interest and non-use values leave no behavioral trace. It is, therefore, no coincidence that non-market valuation is a field in economics where surveys have been widely used.

In contrast to decision utility, experienced utility refers to the hedonic quality of experience, broadly construed to include satisfaction as well as pleasure (Kahneman and Varey 1991). The concept of experienced utility is similar to the original, Benthamite meaning of utility. Empirically, experienced utility can be captured by measures of subjective well-being. Because measures of subjective well-being are fundamental for the life satisfaction approach, we devote a separate section to the discussion of these measures and the corresponding measurement techniques (see section 2.2). The empirical study of subjective well-being used to be the province of hedonic psychology (for surveys, see Diener 1984; Diener et al. 1999; and the

contributions in Kahneman, Diener and Schwarz 1999). However, this interpretation of utility and its measurability by subjective well-being data is largely accepted in the recent development of happiness research. Economists have begun to use these measures to tackle a variety of questions and to shed light on individuals' preferences or utility functions.[1] Examples are studies on the psychological costs of unemployment (e.g. Clark and Oswald 1994; Gerlach and Stephan 1996; Winkelmann and Winkelmann 1998; Clark, Georgellis and Sanfey 2001), the effect of work norms (Clark 2003b; Stutzer and Lalive 2004), utility premiums of public sector employment and sectoral sorting (Luechinger, Stutzer and Winkelmann 2006; Luechinger, Meier and Stutzer 2008), the importance of relative concerns, whereby comparisons may refer to others (e.g. McBride 2001; Senik 2004; Ferrer-i-Carbonell 2005; Luttmer 2005 on status), oneself in the past (e.g. Di Tella, Haisken-DeNew and MacCulloch 2005; Clark et al. 2006 on adaptation), and one's own aspirations (e.g. Easterlin 2001; Stutzer 2004; Bruni and Stanca 2006 on income aspirations), on preferences over inflation and unemployment rates (Di Tella, MacCulloch and Oswald 2001; 2003) and on preferences for inequality (Clark 2003a; Alesina, Di Tella and MacCulloch 2004). Further examples are studies on interdependent preferences such as altruism (Schwarze, J. and Winkelmann 2005) and on time-inconsistent preferences (Gruber and Mullainathan 2005; Benesch, Frey and Stutzer 2006; Oswald and Powdthavee 2007; Stutzer 2007), on preferences for political institutions and processes (Frey and Stutzer 2000; 2005a), politics (Di Tella and MacCulloch 2005b), good governance (Helliwell and Huang 2006) and institutional trust (Hudson 2006) as well as on the importance of social capital and relational activities (Björnskov 2003; Helliwell and Putnam 2004; Helliwell 2006; Bruni and Stanca 2007), religion (Clark and Lelkes 2005; Lelkes 2006; Dehejia, DeLeire and Luttmer 2007) and sex (Blanchflower and Oswald 2004a). The literature is reviewed by Frey and Stutzer (2002a, b), Easterlin (2003; 2005), Layard (2005; 2006) and Clark, Frijters and Shields (2007).

As Kahneman and Thaler (1991) suggest, experienced utility is presumably what people try to maximize and what policies should be about. The use of decision utility can thus only be justified if experience and decision utility coincide or are, at least, closely related. In many situa-

[1] The origins of happiness research in modern economics are usually traced back to Easterlin's (1974) seminal article and his paradoxical observation that there is a noticeable association between income and happiness within countries but that at the same time average happiness does not increase in tandem with the increase in average income over time (see also Easterlin 1995).

tions this may be the case. However, there is evidence indicating that in some situations the two concepts diverge systematically (e.g. Kahneman, Wakker and Sarin 1997; Frey and Stutzer 2004a; Kahneman and Thaler 2006). The divergence of the two concepts of utility has immediate consequences for cost-benefits analysis and the valuation of public goods. On the one hand, standard methods of non-market valuation are based on the concept of decision utility (see also section 2.3.2). On the other hand, the measurability of experienced utility opens up the possibility to directly assess the public goods in utility terms. In section 2.2.3 below we discuss six conditions that should be met in order that measures of subjective well-being can be used for valuing public goods. If these conditions are met, non-market valuation becomes straightforward. The basic idea of the life satisfaction approach is simple. The public good or externality faced by individuals is included as an additional argument in micro-econometric subjective well-being or life satisfaction functions. Technically, multiple regression analyses are conducted and individual life satisfaction is regressed on the public good of interest, income and other covariates. Using the coefficients for the public good and income, it is possible to calculate utility constant trade-off ratios between the public good and income for marginal and inframarginal changes in the public good provision.

## 2.2 Measurement of subjective well-being

The applicability of the life satisfaction approach to value public goods crucially depends on whether subjective well-being is an empirically adequate and valid approximation to experienced utility. In the following, we therefore discuss the current state of research on the subjective well-being measures and measurement techniques. Because a judgment on the adequacy of the data ultimately depends on the intended use, the measures and techniques are evaluated in the last part of this section on the basis of several conditions that are important for valuing public goods.

### 2.2.1 Measures

Subjective well-being is the umbrella term for different measures that can be distinguished along two dimensions. A first dimension distinguishes between different components of subjective well-being, a second between level and duration of well-being. Regarding the first dimension, a common distinction is between cognition, the cognitive, evaluative or judgmental component of well-being, and affect, the pleasure-pain component of well-being (see e.g.

Ostrom 1969; Diener 1984; Veenhoven 1984). With regard to affect, we can differentiate between the two independent components, positive and negative affect (Andrews and Withey 1976). Although this tripartite solution was not always uncontroversial (see e.g. Fordyce 1986), rigorous empirical analysis has shown that cognition, positive affect and negative affect are separable constructs and that cognition meets the criteria of discriminant validity from both the affective components (Lucas, Diener and Suh 1996; Arthaud-Day et al. 2005).[2]

Cognition is usually assessed with life satisfaction. Life satisfaction questions assume that a person makes a global evaluation of his or her life, examines the tangible aspects and conditions, weighs the good against the bad and arrives at a judgment of overall satisfaction. It is presumed that the global nature of this judgment makes it a relatively stable evaluation that is not completely dependent on the affective state the person is in at the time of judgment and is more than an evaluation of the amount of time spent in a positive versus negative mood (e.g. Lucas, Diener and Suh 1996). However, satisfaction measures are not pure indicators of cognition but reflect some affect as well (Andrews and Robinson 1991). This kind of affect contaminated cognition closely corresponds to what has been considered the best theory on the nature of welfare in philosophy (e.g. Sumner 1996, pp. 140-156). Affect, on the other hand, is the label for the combination of moods and emotions and represents people's on-line evalua-

[2] The discussion of subjective well-being deliberately omits objective theories of well-being. Objective theories deny a logical dependence of a subject's well-being on the subject's attitude and typically offer a list of "values" or "goods" that represent different dimensions of welfare (Sumner 1996, p. 38; Adler and Posner 2006, p. 31). This strand of theory has its roots in Aristotle's *Nichomachean Ethics*; Aristotle's ideal of the good life is *eudaimonia*, a life in which the person flourishes and fulfills his or her true potential. This ideal reverberates in modern theories. For example, Waterman's (1993) *summum bonum* is personal expressiveness, a state of feeling alive and authentic, that occurs when people's life activities are congruent with deeply held values and are holistically or fully engaged. The choice of the "positive psychologists" Csikszentmilhalyi (1997) and Seligman (2002) is the *autotelic* personality and the experience of flow. Ryan and Deci's (2000) self-determination theory embraces self-realization as a central definitional aspect of well-being and theorizes that the fulfillment of three psychological needs, autonomy, competence and relatedness, is essential for psychological growth. Ryff (1989) asserts that well-being involves a broad suite of elements including self-acceptance, positive relations with others, autonomy, environmental mastery, purpose in life and personal growth. Nussbaum's (2000) list is even longer and includes life itself, bodily health, bodily integrity, the use of the senses, imagination and thought, the emotions, practical reason, affiliation, interaction with other species, play, and control over one's environment. Sen's (e.g. 1984; 1993) capabilities approach can also be counted among the objective theories with its core notions of functionings, anything which a person manages to do or be, and capabilities, freedom and opportunity to achieve certain functionings. One essential feature of ordinary concepts of welfare is their subject-relativity. Since objectives theories exclude all reference to the subject's attitudes or concerns, they will have to supply some alternative account. Therefore, they are difficult to reconcile with the subject-relativity of welfare (Sumner 1996, pp. 42-44). As Dworkin (1990, p. 77) notes, "my life cannot be better for me in virtue of some feature or component I think has no value." The subjectivists' standpoint does not deny that the values and goods proposed by objectivists are instrumental to reach the goal of increased well-being (see especially the social production function-theory on this point, e.g. Lindenberg 1990); it does, however, deny that they have intrinsic importance. From the subjectivists' perspective, objective theories take the sources of well-being for its nature (Sumner 1996, p. 64).

tions of the events that occur in their lives (Diener et al. 1999). Finally, happiness, another common measure of well-being, lies between the two poles of cognition and affect (Andrews and Robinson 1991).

The second dimension distinguishes between measures that capture a person's level of subjective well-being and the duration in the one rather than another mental state. Because life satisfaction is a relatively stable construct, duration measures usually refer to affect. For example, the U-index discussed below measures the proportion of time an individual spends in an unpleasant state. Thus, the combination of the dimensions entails four typical measures: the level of life satisfaction, the level of positive affect, the level of negative affect (or the difference between the two affective levels) and the duration in one affective state.

### 2.2.2 Measurement techniques

Before we discuss different measurement techniques in detail, it is important to note that the two aspects, measures and measurement techniques, are not independent of each other. For example, while the stable and cognitive component is usually captured by global self-reports, measures with an inherent time components such as the U-index are best captured with real-time or time-use measurement techniques.

*Global self-reports*. Global self-reports are the workhorse technique in happiness research. This approach elicits subjective well-being in large and representative surveys either by single-item or by multi-item questions (see Andrews and Robinson 1991 for a survey). A prominent single-item question of life satisfaction can be found in the German Socio-Economic Panel (GSOEP), which asks: "How satisfied are you at present with your life, all things considered?" Respondents can answer on an 11-point scale from 0 (completely dissatisfied) to 10 (completely satisfied). An example of multi-item questions of life satisfaction is the Satisfaction with Life Scale (SWLS; Diener et al. 1985; Pavot and Diener 1993b). It is the average of five related questions, each of which is rated on a 7-point scale from 1 (strongly disagree) to 7 (strongly agree). The items are: "In most ways my life is close to my ideal"; "The conditions of my life are excellent"; "I am satisfied with my life"; "So far I have gotten the important things I want in life"; "If I could live my live over, I would change almost nothing". A single-item affect measure is the Affect Grid (Russell, Weiss and Mendelsohn 1989), a multi-item affect measure the Positive and Negative Affect Schedule (PANAS; Watson, Clark and

Tellegen 1988). The PANAS consists of ten positive affects (interested, excited, strong, enthusiastic, proud, alert, inspired, determined, attentive, and active) and ten negative affects (distressed, upset, guilty, scared, hostile, irritable, ashamed, nervous, jittery, and afraid). Participants are asked to rate items, based on the strength of emotion, on a scale from 1 (very slightly or not at all) to 5 (extremely).

Multi-item questions have higher reliability because random measurement errors tend to be cancelled out across the different items; further, they are able to reflect different aspects of subjective well-being (Andrews and Robinson 1991; Pavot and Diener 1993a). The downside is that multi-item questions may prompt respondents to search their memory for evidence relevant for a particular item and, thereby, give this particular aspect more weight than it otherwise would carry. In the same way, multi-item questions give different aspects arbitrary weights, whereas single-item questions rely on respondents' integration of different aspects.

Measures of global self-reports passed a series of validation exercises. As cognition and affect are separable constructs, a separate discussion of the validity and reliability of the measures is required.[3] Respondents who are satisfied with their lives are also rated as satisfied by family members and friends (Pavot et al. 1991; Pavot and Diener 1993a; Sandvik, Diener and Seidlitz 1993; Lepper 1998) and by experts (Sandvik, Diener and Seidlitz 1993). Life satisfaction scores correlate with other variables that can be plausibly claimed to be associated with true utility (e.g. Di Tella and MacCulloch 2006). In two 20-year follow-up studies, low levels of reported life satisfaction predicted all-cause, disease and injury mortality, especially for male respondents (Koivumaa-Honkanen et al. 2000) and suicide (Koivumaa-Honkanen et al. 2001). At the national level, life satisfaction and suicide rates are also associated (Helliwell 2004; 2006), but the ecological fallacy prevents us from making strong inferences regarding the validity of self-reported life satisfaction. Satisfied individuals are less likely to suffer from hypertension, a relationship that even translates into a correlation between hypertension and satisfaction at the national level (Blanchflower and Oswald 2007). Finally, life satisfaction predicts both, future marriage (Stutzer and Frey 2006) and future marital break-up (Gardner and Oswald 2006). As is the case with life satisfaction measures, self-reported affect correlates

[3] One often cited validation result is that different measures of well-being correlate with one another, allegedly revealing a single unitary construct underlying the different measures. However, this is at best evidence for missing discriminant validity of different life satisfaction and affect measures. Not surprisingly, this view is most vehemently expressed by Fordyce (1988) who is an advocate of the single-component solution.

with ratings by family members and friends (Costa, P. T. and McCrae 1988; Sandvik, Diener and Seidlitz 1993; Lepper 1998) and by experts (Sandvik, Diener and Seidlitz 1993). Self-reports of subjective emotional experience during a movie screening also correlate with (Duchenne) smiling (Ekman, Friesen and Davidson 1990). Individuals expressing a high level of positive affect are less likely to catch a cold when exposed to a cold virus, recover faster if they do (Cohen et al. 2003) and produce more antibodies after vaccination (Morag et al. 1999). Emotional content expressed in autobiographical sketches of a cohort of nuns entering the convent predicts longevity, even though most factors influencing longevity were identical or similar for the rest of the nuns' lives (Danner, Snowdon and Friesen 2001). In sum, measures of life satisfaction and affect correlate with judgments of others, objective circumstances and physiological phenomena, and they can predict behavior. Although no single piece of evidence on its own is decisively convincing, the body of evidence lends credibility to the validity of the subjective well-being measures.

Different studies assess the reliability of the measures using test-retest correlations. Life satisfaction exhibits strong correlations of above 0.8 over short time intervals (between 2 weeks and 2 months; Pavot et al. 1991; Alfonso and Allison 1992; Pavot and Diener 1993a), weaker correlations of mostly above 0.5 but below 0.75 over the medium term (between 9 months and 4 years; Atkinson, T. 1982; Headey and Wearing 1989; Magnus et al. 1992; Lepper 1998; Ehrhardt, Saris and Veenhoven 2000) and weak correlations of around 0.3 in the long run (11 years; Ehrhardt, Saris and Veenhoven 2000). This pattern makes sense if life satisfaction is a stable construct but sensitive to changing life circumstances. Sensitivity to changing life circumstances has also been explicitly tested and confirmed (Atkinson, T. 1982; Ehrhardt, Saris and Veenhoven 2000). Affect measures have a test-retest correlation of slightly above 0.5 over a 9 month interval (Lepper 1998) and correlations of between 0.35 and 0.4 over a 2 year interval (Headey and Wearing 1989). Thus, test-retest reliability is lower for affect measures than for life satisfaction measures, a result that is well in accordance with the nature of the different components of subjective well-being.

As subjective data are based on individuals' judgments, they are prone to a multitude of biases. Studies document indeed a number of systematic and non-systematic biases. Some of these biases will be discussed in more detail in section 2.2.3 below. However, we will briefly discuss retrospective recall biases because they are important to the understanding of the po-

tential merits of the measurement techniques presented below. In various experiments (documented in Kahneman, Wakker and Sarin 1997; Kahneman 1999; Kahneman and Thaler 2006) participants recorded their real-time experience of a painful procedure and, in addition, provided a global retrospective evaluation of the procedure. The global evaluations closely followed peak-end evaluations, i.e. the average of the peak affective response during the procedure and the end value recorded. Hence, the global evaluations systematically differ from total experienced pain, defined as the temporal integral over the moment-by-moment evaluations. Although Kahneman (1999, p. 19) warns that the conclusions should not be extended beyond the range of the experimental situations, two implications for global self-reports do emerge: First, global self-reports may be influenced by cognitively accessible and salient memories and by recent events. Second, in retrospective evaluations, people tend to neglect the duration of different episodes. Whether this bias is detrimental for empirical research depends on the answers to two questions. The first question is normative and asks what the right approximation for utility is. Total pain or total utility are normative concepts that assume that life is experienced as a series of discrete, momentary hedonic satisfactions, time-neutral weighting of these moments and time separability of utility (Kahneman, Wakker and Sarin 1997). Of course, all assumptions are open to debate (e.g. Sumner 1996, p. 148; Kelman 2005). The second question is whether retrospective recall biases have a systematic influence on empirical results. Most likely, the idiosyncratic effects of recent, irrelevant events average out in representative surveys (Kahneman and Krueger 2006).

*Experienced sampling method (ESM) or ecological momentary assessment (EMA)*. In ESM studies, participants are prompted in their natural environment to record their momentary or near-momentary affective state, together with information on where they are, what they are doing and whom they are with. The records are collected several times per day at random instances of time with handheld computers, beepers reminding respondents to write down the information or printed schedules (introductory surveys of the method are given in Brandstätter 1991; Stone, Shiffman and DeVries 1999; Scollon, Kim-Prieto and Diener 2003).[4] The method is aimed at mitigating recall biases and allows researchers to examine the influence of the immediate environment and fluctuations of affect. Given the relatively stable nature of life satisfaction, ESM studies generally focus on the affective component of subjective well-being.

[4] See Csikszenhmihalyi and Larson (1987) for a review on reliability and validity studies of the ESM.

Exceptions are Steptoe, Wardle and Marmot (2005) eliciting respondents' happiness and Riis et al. (2005) eliciting overall life satisfaction on 10% of the prompts.

Major drawbacks of the ESM method are its high cost and the burden it poses on respondents. These drawbacks are the reason for the typically small and unrepresentative samples. The samples are unrepresentative because they are often drawn from particular sub-groups of the population and because of a self-selection bias. The samples in ESM studies on subjective well-being range from around 40 students (Thomas and Diener 1990; Oishi 2002) to slightly over 800 primary school students (Csikszentmihalyi and Hunter 2003).

ESM studies coupled with global self-reports allow researchers to assess the importance of retrospective recollection biases. In a study of 49 hemodialysis patients and 49 healthy controls by Riis et al. (2005), recollections are accurate for the hemodialysis patients, but recollections significantly underestimate the average ESM response in the group of healthy controls. Scollon et al. (2004) find that in their sample of 416 students recollections closely correspond to real-time measurements. Moreover, the rank ordering of different groups is maintained across different measures.

*Day reconstruction method (DRM)*. The DRM is similar in spirit to the ESM, but addresses several problems of the ESM such as the high costs and the burden on the respondents as well as the infrequent sampling of rare activities. In DRM studies, respondents are asked to reconstruct the activities of the preceding day by constructing a diary and by indicating when an episode began and ended, what they were doing, where they were and whom they were with. They then state how they felt during the episode on selected affect dimensions. Evoking the context of the previous day is intended to elicit specific and recent memories, thereby reducing recall biases. Hence, the DRM is a hybrid approach combining features of time-budget measurement common in time-use studies and experience sampling (see Kahneman et al. 2004b, c for a description of the method).

In DRM studies, respondents' answers can be summarized in different measures. A first measure is "net affect" (see e.g. Kahneman et al. 2004c); an individual's net affect is the duration-weighted average over all episodes of the average positive adjectives less the average of the negative adjectives. Another measure is the "U-index", where the "U" stands for "unpleasant" or "undesirable" (Kahneman and Krueger 2006). The U-index corresponds to the

proportion of time an individual spends in an unpleasant state. The dichotomous categorization of moments is achieved by classifying a moment as unpleasant if the most intense feeling for that moment is a negative one. Kahneman and Krueger (2006) justify this categorization by asserting that one dominant emotion colors an entire period. The correlation between these two measures of affect is -0.79; the correlation between net affect and global life satisfaction is 0.34, the correlation between the U-index and global life satisfaction is -0.26 (own calculations based on the data of Kahneman et al. 2004b, c). Thus, the different measures seem to capture different aspects of subjective well-being. The test-retest correlation over a 2-week period is similar for all measures: 0.59 for life satisfaction, 0.64 for net affect and 0.50 for the U-index (Krueger and Schkade 2007).

The diurnal pattern of affect found in DRM studies is very similar to the pattern found in ESM studies. This suggests that the methods are able to capture the same aspects and that, thus, the DRM is a more efficient substitute method for the ESM (Kahneman et al. 2004b).

*Physiological measures*. Two different views can be found in the literature concerning the role of physiological measures. According to a first view, physiological measures are substitutes or at least complements to self-reports and allow for a precision in subjective well-being research previously limited to the natural sciences (e.g. Larsen and Frederickson 1999). As Kelman (2005) points out, the significance of physiological responses is ultimately parasitic on self-reports. Physiological responses are thought to measure subjective well-being because they correlate with self-reports. Thus, if self-reports are inaccurate, physiological measures become uninterpretable. A second view assigns physiological measures a more humble, but currently more realistic, part: a further validation of subjective self-reports.

Various physiological correlates of well-being have been documented. However, subjective well-being does not always manifest itself in reliable physiological markers and often the exact relationship between a physiological phenomenon and subjective experience is unclear (see e.g. Sapolsky 1999). We focus, therefore on two neural correlates of well-being that have received considerable attention: activation asymmetry of the prefrontal cortex and activation asymmetry of the amygdala (see Davidson 2003; 2004 for surveys).[5]

[5] See the surveys by Zak (2004), Camerer, Loewenstein and Prelec (2005) and Fehr, Fischbacher and Kosfeld (2005) on how neuro-science can inform economics in other areas.

Early research on prefrontal activation asymmetry was spurred by clinical observations on the link between stroke-related lesion and affective symptomology (e.g. Robinson et al. 1984). More recent research is experimental and uses electro-encephalography (EEG). Activation asymmetry is measured as the difference in alpha power density between the right and left prefrontal cortex. Alpha waves are the dominant brain wave activity of awake adults and can either be measured when participants are at rest (tonic or resting activation) or when they are exposed to emotional stimuli (phasic activation). Resting anterior EEG asymmetry correlates with reported affect in the PANAS (Tomarken et al. 1992), global life satisfaction expressed on the SWLS (Urry et al. 2004) and reactivity to experimental elicitors of emotion (Wheeler, Davidson and Tomarken 1993). In right-handed individuals, more left-sided and less right-sided hemispheric activation at baseline is associated with higher subjective well-being, stronger reactivity to positive emotion elicitors and less vulnerability to negative emotion elicitors. Over a 3-week time interval, measures of activation asymmetry have a relatively high test-retest correlation of 0.65 to 0.75 (Tomarken et al. 1992). However, the degree of asymmetry is far from being a fatality. Positive and negative stimuli induce short run variance with the phasic influence being superimposed upon the more tonic differences in the asymmetry (Davidson and Tomarken 1989). In the medium-term, changes in activation asymmetry have been found in people randomly assigned to meditation groups compared to people assigned to a control group (Davidson et al. 2003).

Neuroimaging techniques, such as positron emission topography (PET) and functional magnetic resonance imaging (fMRI), make it possible to analyze another important structure in the emotion circuitry of the brain, the amygdala. Differences in both resting and phasic amygdalar activation asymmetry predict dispositional affect. Subjects with greater tonic or phasic activation in the right amygdala report greater negative affect (Abercrombie et al. 1998; Irwin et al. 1998).

### 2.2.3 Evaluation of measures and measurement techniques

All of the four measurement techniques and their corresponding measures have their strengths and weaknesses. Which measure and measurement technique is to be preferred depends ultimately on its intended use. In the following, we evaluate the measures on the basis of six criteria that are relevant for the evaluation of public goods: the measures of subjective well-being

should (i) be broad and inclusive, (ii) refer to respondents' present situation, (iii) have small measurement errors, and no systematic ones (iv) be interpersonally comparable, (v) have a cardinal meaning, and (vi) be available at a sufficiently large scale (at a sufficiently low cost).

*Inclusiveness*. Essentially, this criterion asks whether subjective well-being is an appropriate empirical approximation of experienced utility or individual welfare. The broad consensus in happiness research considers subjective well-being to be a good empirical approximation for experienced utility (e.g. Frey and Stutzer 2002b; Di Tella and MacCulloch 2006). Critics claim that subjective well-being is extremely narrow and constitutes only one of many components of individual welfare (Adler and Posner 2006, p. 77), one sub-utility function among others (Kimball and Willis 2006). This debate parallels the normative question of the nature of welfare with the "objectivist" ascribing various goods intrinsic importance and "subjectivists" conceding other goods only instrumental importance insofar as they contribute to well-being (see footnote 2). The positive question asks whether other "higher order" goods are sub-utility functions of equal standing with subjective well-being or whether these goods are arguments in the subjective well-being function with no independent effect on individual utility. This question is of uppermost importance whenever data of subjective well-being are used to analyze issues involving trade-offs, i.e. all issues with political and economic importance. Data on subjective well-being can only be used to shed light on individual decision making and errors in decision making or to evaluate policies if subjective well-being is a broad and (all-)inclusive concept. As Adler and Posner (2006, pp. 88-100) note, narrow measures used for policy evaluation have a high intrinsic inaccuracy in distinguishing between projects which increase and such that decrease welfare. Hence, the degree of inclusiveness is of immediate importance for the life satisfaction approach. Assume, for the sake of argument, that subjective well-being is one sub-utility function together with health and the ability to care for the family. If this is the case, public goods such as security and environmental quality as well as income are likely to affect overall utility mostly through these other sub-utility functions. The trade-off between the public goods and income (or any other policy relevant variable) is then not adequately reflected in subjective well-being. If, on the other hand, health and the ability to care for the family are mere arguments in the subjective well-being function, the utility constant trade-off ratio between public goods and income can be extracted from subjective well-being data.

The strategy of the critics is to equate subjective well-being with pleasure and pain and declare the ESM or DRM as the gold standard of measurement techniques. They then reject the view that subjective well-being thus understood is a meaningful measure of overall utility and extend the conclusions beyond the narrower measure to happiness research as such. This victory over measures of subjective well-being is cheap and hollow. As we have seen, there is a wide array of measures and measurement techniques. Since the components of life satisfaction and affect are potentially distinct, it is important to establish for each component the degree of inclusiveness. The relative degree of inclusiveness can be assessed empirically by investigating whether the correlate of one component also correlates with other components. However, it is important to note that this approach does not allow us to determine the absolute degree of inclusiveness, but only the relative one.

Table 1 depicts the correlations of various personal and job related characteristics with global life satisfaction, duration weighted net affect and the U-index; the correlations are based on the data of the DRM study reported in Kahneman et al. (2004b, c). Only life satisfaction is correlated with most personal characteristics reflecting general circumstances. An exception is the weak correlation between age and net affect. A similar picture emerges for job characteristics. While some long-term job characteristics such as the opportunity to help others have a positive effect on subjective well-being according to all measures, other long-term characteristics such as the possibility to work at home or telecommute have only and effect on life satisfaction but not on the affect measures. On the other hand, features of the immediate work situation such as the opportunity to chat with coworkers positively influence reported affect but not life satisfaction. In a new DRM study, Kahneman et al. (2006) report similar results.

*Table 1*. Covariates of different subjective well-being measures

| | Life satisfaction | Net affect | U-index |
|---|---|---|---|
| *Personal characteristics* | | | |
| ln(HH income) | 0.20** | 0.05 | -0.04 |
| Age | 0.12** | 0.07(*) | -0.04 |
| Married | 0.14** | -0.01 | 0.00 |
| Has children | 0.03 | 0.03 | -0.01 |
| Years of education | 0.20** | 0.04 | -0.01 |

*To be continued*.

*Table 1*, part 2

| | Life satisfaction | Net affect | U-index |
|---|---|---|---|
| *Job characteristics* | | | |
| Opportunity to help | 0.14** | 0.15** | -0.11** |
| Low job security | -0.12** | -0.07* | 0.04 |
| Opportunity to chat | -0.01 | 0.06(*) | -0.06(*) |
| Work at home/telecommute | 0.10** | 0.02 | 0.00 |

*Notes*: Life satisfaction is elicited on scale ranging from 1 ("not at all satisfied") to 4 ("very satisfied"). Net affect is the duration-weighted average over different episodes of a respondents' day of the average of three positive adjectives (happy, warm/friendly, enjoying myself) less the average of six negative adjectives (frustrated/annoyed, depressed/blue, hassled/pushed around, angry/hostile, worried/anxious, criticized/put down). All adjectives are reported on a scale ranging from 0 ("not at all") to 6 ("very much"). The U-Index is the proportion of each person's time engaged in an activity in which the dominant emotion was negative. Sample consists of one day in the life of 909 employed women in Texas.
*Source*: Own calculations based on the data of Kahneman et al. (2004b, c).

The results in table 1 parallel earlier findings. Diener and Biswas-Diener (2002) report higher correlations between income and global happiness or global satisfaction than between income and measures of affect for U.S. samples. In their ESM study on adolescents, Csikszentmihalyi and Schneider (2000) even find a small but statistically significantly decreasing trend in happiness across respondents in higher socioeconomic status communities. Overall, therefore, measures of affect, especially those captured with ESM and DRM, are not correlated with factors that play an important role in preanalytic convictions and ordinary theories of welfare. Hence, they lack descriptive adequacy (Sumner 1996, pp. 10-20) and may indeed be too narrow for the present purpose, i.e. valuing public goods.

*Reference to presence*. Measures of subjective well-being should refer to the respondents' present lives and represent their period- or flow-utility. If scores of subjective well-being reflected discounted expected future utility, it would become difficult to relate changes in objective circumstances to changes in subjective well-being.

In measures of global self-reports, the focus on the present situation is often indicated by means of the wording of the question. Often the questions have extensions such as "these days", "now", "nowadays" or "at present". In the ESM and DRM, the focus on the presence or, more precisely, on the moment to be assessed naturally arises from the method itself and is made explicit in the question. For example, a typical DRM questionnaire asks "How did you feel during this episode?" (Kahneman et al. 2004a; emphasis removed).

*Measurement errors*. The major concern in the discussion of degree of inclusiveness was that measures of subjective well-being may exclude important aspects of utility. The converse concern is that measures of subjective well-being include a lot of noise and are contaminated by confounding factors. Most research on this problem has focused on global self-reports.

Normally, the global judgments are only construed when asked. Answering the question involves cognitive (memory and aggregation) and communicative processes. At the level of the cognitive processes, concerns may arise that respondents may make little mental effort and instead rely on easily accessible information (Larsen and Frederickson 1999; Schwarz and Strack 1999; Bertrand and Mullainathan 2001). Experimental research shows that self-reports can be influenced by the immediate context as well as by artificially induced intra- and interpersonal comparisons and temporal mood states (see Schwarz and Strack 1991; 1999 for references). At the level of the communicative process, issues of communicative norms, self-representation and social desirability become important (Larsen and Frederickson 1999; Schwarz and Strack 1999; Bertrand and Mullainathan 2001).

In order to assess the importance of these findings for the life satisfaction approach, it is useful to integrate them into a measurement error framework (Bertrand and Mullainathan 2001; Ravallion and Lokshin 2001). This allows us to distinguish two types of errors: White noise errors that are unrelated to right hand side variables on the one hand, and systematic errors that are correlated with the explanatory variables on the other hand. Mood variability and most context effects fall in the first category. Conceptually, errors of this sort pose no problem. They entail no systematic bias as the idiosyncratic effects cancel each other out. However, the random variation reduces the statistical fit. Therefore, the ratio of error variance to true variance has to be sufficiently low to make statistical work productive. There is substantial evidence for this. Eid and Diener (2004) use a structural decomposition model to separate random error and situation variability (in our context also random error) from basic stability. For life satisfaction, only between 4% and 10% of the observed variance in life satisfaction is due to measurement errors, and between 12% and 16% due to occasion-specific variability. Measurement error and occasion specifity coefficients are slightly larger for measures of affect. Therefore, differences in the immediate context and temporary mood have a smaller effect if

they occur in natural settings than if they are manipulated in the controlled environment of experiments.[6]

Measurement errors that fall into the second category pose a more serious problem. Two findings of the experimental research are of potential relevance for the life satisfaction approach. First, other questions in the questionnaire and the order of the question can influence the reported subjective well-being. If the questionnaire includes questions referring to the public good to be evaluated and to income, these questions may systematically bias the results, especially if the questions precede the subjective well-being question. On the one hand, the questions increase the accessibility of information on the public good and income and heighten their awareness, thereby increasing the weight of these aspects in the global judgment. On the other hand, conversational norms of non-redundancy may decrease the weight of these aspects. The latter effect is to be expected if questions of satisfaction with the public good or satisfaction with income immediately precede the subjective well-being question. Both effects have been documented (Strack, Martin and Schwarz 1988). Second, answers deemed to be socially desirable or serving self-representation purposes can also systematically influence the results. For example, a well-to-do respondent may want to live up to the expectations of observers and state an overly high satisfaction. Or, a pauper may refuse to admit failure and also state an overly high satisfaction. Both kinds of answering behavior would obscure the true relationship between income and subjective well-being. Thus, problems of the second category have important implications for the questionnaire design and survey mode as well as for the choice of existing data.

ESM and DRM are both measurement techniques that lessen or even remove the cognitive burden in memory and aggregation processes. Contextual factors should, therefore, have less influence on the answers (Schwarz and Strack 1991; 1999). Similarly, as the problems are attributed to cognitive and motivational deficiencies in observing and reporting own subjective well-being, physiological measures are not afflicted by contextual factors. Mood effects are also of less importance because mood is part and parcel of the concept of affect that is usually assessed by these techniques. Of course, the latter aspect only counts as a factor reducing measurement errors if affect is the correct concept.

[6] Careful questionnaire design, choice of appropriate response scales and interview mode can further reduce measurement errors (Cummins and Gullone 2000; Kroh 2006).

*Interpersonal comparability*. The problem of the impossibility of interpersonal welfare comparisons has two different aspects: First, it is not possible to observe the level of an individual's utility and, therefore, compare utility levels of different persons in standard scientific ways (e.g. Robbins 1938). Individuals with identical preferences (as revealed through behavior) and with identical expressive reactions to any situation may nevertheless attach different utilities to identical situations. People can have different susceptibilities to satisfaction and identical orderings of alternatives are compatible with different absolute levels of utility. Further, identical expressive reactions may well indicate different mental states. Respondents may convert their true inner utility differently into expressions of subjective well-being with some respondents' reported well-being responding more strongly to changing life circumstances than others'. Harsanyi (1955) calls this the metaphysical problem. The second problem is one of morale and can be reduced to the question of whether people with higher susceptibility to satisfaction and stronger (possibly exaggerated) expressions of feelings should get more weight in collective decisions (e.g. Scanlon 1991). The relevant questions in the present context are whether identical (verbal and physiological) expressions reflect identical mental states and what the consequences for empirical research are if they do not.

Kahneman (2000) suggests that there is evidence of considerable interpersonal convergence in ranking of pleasure and pain. In painful medical procedures, for example, the relationship between expressed pain and physiological reactions is similar across persons. Similarly, the correlations between self- and other-reports discussed above show that self-reports are not just artifacts of individual specific response behavior but are related to shared standards of evaluation. More importantly, for most empirical research (including research using the life satisfaction approach), comparisons at the individual level are not necessary. Instead, empirical analysis is focusing on groups and compares the subjective well-being of individuals under different circumstances, e.g. the subjective well-being of groups of individuals exposed to different levels of a public good. By focusing on groups, personal peculiarities of individuals counterbalance one another (for this reason, intergroup comparison was already advocated by Marshall 1920, p. 152).

The questions thus becomes whether there are difficulties with intergroup comparisons of well-being. In this respect, there are reasons for concern, especially for groups at the bottom or the top of subjective well-being scales. First, the bounded nature of subjective well-being

scales makes it impossible to adjust self-reports of persons already at the bottom/top of the scale if the situation further deteriorates/improves. Second, as respondents approach the bottom/top of the scale, self-reports may become less sensitive to changes in true inner utility because respondents want to preserve their possibility to indicate further changes. Third, the way in which people interpret scales can change owing to self- and scale-norming effects (on self- and scale-norming, see Frederick and Loewenstein 1999). These problems can make it difficult or impossible to establish the exact relationship between experienced subjective well-being and its covariates. For example, Oswald (2005) disagrees with the common view held in happiness research that the concave relationship between happiness and income is evidence for diminishing marginal utility. He draws a distinction between concavity of the utility function and concavity of the reporting function, i.e. the function relating reported well-being to actual well-being with unknown curvature. These problems are likely to be less important if subjective well-being effects of a variable analyzed are likely to be small as it is the case with many public goods.

Overall, there are no apparent differences between the various measures of subjective well-being with two potential exceptions: the U-index and physiological measures. Kahneman and Krueger (2006) developed the U-index with the explicit aim of addressing the related problems of interpersonal comparability and cardinality (discussed below). As explained, with the U-index, an episode is classified solely according to the most intense feeling expressed. The classification is, therefore, largely independent from interpersonal differences in the use of the scales and does not rest on a cardinal interpretation of the scales. However, as Kahneman and Krueger (2006) acknowledge, an identical proportion of time spent in episodes with the single most intense feeling being an unpleasant one does not necessarily or generally imply a similar hedonic experience. Furthermore, the U-index relies on the intrapersonal comparable use of the scale for different feelings. If self- and scale-norming effects are not uniform across feelings, the U-index loses much of its informational content. Physiological phenomena such as the activation asymmetry of the prefrontal cortex can be measured in objective, interpersonal comparable units. However, there is of course no a priori reason to assume that the physiological phenomena are experienced in an interpersonal comparable way.

Hence, Robbins' (1938) statement that utility cannot be interpersonally compared with standard scientific rigor still holds and pertains to all measures of subjective well-being. But it is

important to remember that without the assumption of interpersonal comparability of utility, no form of cost benefit analysis is possible (e.g. Van Praag and Frijters 1999) and, in fact, economics can say nothing in way of prescription (e.g. Robbins 1938). Further, intuition, ordinary practice and the widespread use of interpersonal comparisons in moral theorizing all undercut the view that these comparisons are impossible (Adler and Posner 2006, p. 43).

*Cardinality*. Subjective well-being scores are reported on an ordinal scale. Again, the same is true for the physiological measures even though they are usually measured in cardinal units. For example, there is no reason to believe that an increase in the EEG alpha asymmetry by one microvolt squared is experienced similarly at different base levels of activation asymmetry. Using adequate statistical techniques such as the two common ordered response models, ordered probit or ordered logit, the ordinal information is sufficient to calculate individuals' implicit willingness-to-pay (*WTP*). However, in many applications, similar results are obtained when interpreting the scores of subjective well-being in cardinal terms (Ferrer-i-Carbonell and Frijters 2004). This is consistent with the validation results of the income evaluation approach. In a context free setting, respondents translated verbal labels on a numerical scale roughly in a cardinal manner (Van Praag 1991).

In the applications of the life satisfaction approach in chapters 4 and 5, we also report the *WTP* estimates based on ordered probit estimates. As can be seen, the results based on the two methods are very similar and differ by less than 5% on average.

*Availability and costs*. Most public goods can be expected to have relatively small effects on subjective well-being, in particular, smaller effects than personal characteristics. In order to statistically detect the effects, large sample sizes are required. Therefore, the cost component is another criterion for evaluating measures and measurement techniques. Beyond doubt, the least expensive measurement technique are surveys including global self-reports. The most expensive measurement techniques are probably the ESM and physiological techniques, the DRM falling between these two extremes. These cost differences are reflected in sample sizes in the past. For example, while the GSOEP with a life satisfaction question interviews over 22,000 individuals each year (this figure refers to 2004), sample sizes for the ESM are below 1,000 individuals (and usually much smaller) and sample sizes of neuro-physiological measures usually below 100. In the case of neuro-physiological measures, large and repre-

sentative samples are also difficult to achieve because the measurement apparatuses are located at few sites. However, both factors may become less important in the future. The affordability of tools used in ESM is growing (Scollon, Kim-Prieto and Diener 2003); similarly Camerer, Loewenstein and Prelec (2005) speculate that the portability of EEG will eventually reach the point where it will be possible to take unobtrusive measurements from people as they go about their daily affairs.

The identification of the effect of public goods on subjective well-being often requires samples with respondents living in different geographical areas, e.g. different countries or different regions. Up to now, only data containing global self-reports meet this criterion, but the first DRM study on a global scale is under way (Kahneman in email to Frey; March 6, 2007).

*Summary of evaluation*. Table 2 summarizes the evaluation by noticing which of the six criteria the four measurement techniques and their corresponding measures meet.

It is important to note that the criteria are neither of equal importance nor independent of each other. For example, at a conceptual level, a sufficient degree of inclusiveness is a *sine qua non*. On a practical level, availability of subjective well-being is another binding constraint. Compared to these criteria, the impossibility of interpersonal comparison and ordinality of utility may seem as mere obsessions of economists. Several criteria are related. For example, the ESM and DRM are only associated with less measurement errors compared to global self-reports if instantaneous affect is the right concept to be measured.[7] Further, the higher precision of the ESM, DRM or of physiological measures leads to a better statistical fit, thereby reducing the necessary sample size. Overall, despite the unfavorable treatment in the literature, for the purpose at hand, the global self-reports score high.

The review of measures and measurement techniques emphasized the strengths and weaknesses of the techniques and their corresponding measures. Hopefully, it also showed "that the measurement of experienced utility should be viewed as a difficult technical problem, not a hopeless quest" (Kahneman, Wakker and Sarin 1997, p. 394).

[7] As explained in section 2.2.2, in DRM studies, respondents do not actually report their affect instantaneously. Nevertheless, by evoking the context of specific episodes of the previous day, thereby reducing errors and biases of recall, the DRM aims at capturing instantaneous affect. For example, Kahneman et al. (2004b, p. 1777) write that "the DRM is intended to reproduce the information that would be collected by probing experiences in real time".

*Table 2*. Evaluation of measures and measurement techniques

| | Global self-reports | | ESM/EMA | DRM | Physiological measures |
|---|---|---|---|---|---|
| | Life satisfaction | Affect | | | |
| Broad and inclusive | Yes | No | No | No | No |
| Refer to present situation | Not necessarily | Not necessarily | Yes | Yes | Yes |
| Low and no systematic measurement errors | No | No | Yes | Yes | Yes |
| Interpersonally comparable | No | No | No | No | No |
| Cardinal interpretation | No | No | No | No | No |
| Available at large scale | Yes, even retrospectively | Yes, even retrospectively | No | Not yet | No |

## 2.3 Comparison with alternative approaches

Economists have developed several ingenious methods to value public goods. The two main avenues pursued have been *stated preference methods* on the one hand and *revealed preference methods* on the other hand. The principal difference between stated and revealed preference methods is that the former draw their data from people's responses to hypothetical questions and the latter from observations of real-world choices. In the following, we discuss the most prominent methods and their inherent problems. In order to highlight the strengths of the life satisfaction approach, the focus is on those problems which the life satisfaction obviates.

### 2.3.1 Stated preference methods: Contingent valuation

By far the most often used stated preference method is the contingent valuation method.[8] The contingent valuation method is a survey based technique of non-market valuation (for introductions see Mitchell and Carson 1989; Boyle 2003; Freeman 2003, pp.161-172).[9] It involves asking people directly about the values they place on a public good by creating a hypothetical market or referendum situation.[10] Thus, the core of every contingent valuation survey is a question eliciting respondents' *WTP* for the particular public good. This question can either be open-ended or a dichotomous-choice. A typical open-ended question asks respondents "how much would you pay" for the specified change in public good provision. The dichotomous-choice question asks respondents "would you pay $x" for the specified change. Dichotomous-choice questions are often framed as a referendum, i.e. they are often combined with the decision rule that the change in public good provision will be implemented if at least 50% of respondents answer in the affirmative. Dichotomous-choice questions reveal only an upper or a lower bound of an individual's *WTP*. However, if it is applied to a large sample of individuals and if the bid amount "x" is varied over different individuals, responses can be used to estimate *WTP* functions.

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[8] Other stated preference methods are, for example, contingent rankings, choice experiments and conjoint analyses (Holmes and Adamowicz 2003).

[9] See Carson et al. (2003) for an elaborate and state-of-the-art contingent valuation study; they estimate individuals' *WTP* to prevent another Exxon Valdez type oil spill. The survey was administered to a national sample of U.S. households and was designed to capture both, use and non-use values. The median *WTP* is around $30, the mean around $97 (in 1990 U.S. dollars).

[10] It is called "contingent" valuation because people are asked to state their *WTP*, contingent on a specific hypothetical scenario and description of the public good or policy.

Stating a *WTP* for a public good is an unfamiliar situation and gives rise to problems of strategic responses. Therefore, the credibility, validity and reliability of results based on contingent valuation are the subject of heated controversy in economics. Skepticism is largely based on the empirically observed "embedding effect" (Kahneman and Knetsch 1992) that refers to several interrelated regularities in contingent valuation surveys. First, in some studies, the *WTP* is almost independent of the quantity of the public good provided (insensitivity to scale and scope). Second, if multiple goods are valued in one survey, the *WTP* for a particular public good often depends on its position in the sequence (sequencing effect). Finally, the sum of the *WTP* for individual changes separately exceeds the *WTP* for a composite change in a group of public goods (sub-additivity effect). Critics see the "embedding effect" as evidence for the non-existence of individual preferences for the public good; individuals receive positive feelings from expressing support for good causes and, accordingly, the survey process creates the values it seeks to reveal (e.g. Diamond and Hausman 1994). However, meta-analyses find significant sensitivity to scale and scope (e.g. Smith, V. K. and Osborne 1996) and, according to proponents, the sequencing and the sub-additivity effect can be explained in terms of substitution effects and diminishing marginal rates of substitution (e.g. Hanemann 1994; Carson, Flores and Meade 2001).

A number of guidelines have been developed to assure credibility, validity and reliability (Arrow et al. 1993; Portney 1994). The most important are the presentation of adequate information, the choice of a credible (hypothetical) method of public good provision and payment mechanism and the use of the referendum format. Contingent valuation surveys usually include information on the public good in question. For some public goods such as clean air, information would often include a range of dose-response relationships between pollution exposure and health effects. In order to reduce the cognitive burden for the respondents but at the same time avoiding having to rely on respondents' previous knowledge, a common practice is to value pollution related morbidity and mortality risks instead of changes in pollution levels (see e.g. Alberini et al. 1997). In combination with dose-response relationships, this allows to value the health related benefits of clean air. However, this approach neglects important benefits of clean air such as reduced material damage, improved visibility and minor symptomatic discomforts including watering eyes, chest pain and general malaise. Providing adequate information also includes reminding respondents of substitutes and their budget constraint. The

other design elements aimed at reducing the unfamiliarity of the task and the danger of symbolic valuation are the hypothetical method of provision and the hypothetical payment mechanism. Respondents are usually asked to value a policy that provides a public good rather than the public good itself. This is complicated by the fact that the chosen method of provision may provide unintended clues to respondents that affect their decision (Boyle 2003). Further, as the case of terrorism and the failure of most traditional anti-terrorism policies suggests, there will often be no consensus on what the effective policies are (see e.g. Enders and Sandler 1993; Frey and Luechinger 2003; Frey 2004 on anti-terrorism policies). The choice of a hypothetical payment mechanism (e.g. price increase, tax increase etc.) often requires a balancing of realism against payment mechanism rejection (Mitchell and Carson 1989). In order to reduce the strategic bias, the guidelines prefer the referendum format. The referendum format is the only elicitation format that is – at least under certain circumstances – incentive-compatible (for a discussion of incentive compatibility of hypothetical referenda see Cummings 1997; Haab, Huang and Whitehead 1999; Smith, V. K. 1999).

Despite these guidelines, the two basic problems of the contingent valuation method – symbolic valuation and strategic bias – are difficult to overcome. The hypothetical nature of the questions asked and the unfamiliarity of the task often entail superficial answers and symbolic valuation in the form of attitude expression (Kahneman and Ritov 1994; Kahneman, Ritov and Schkade 1999). This is well demonstrated in a contingent valuation analysis of a flood reduction project in Roanoke, Virginia (Thunberg and Shabman 1991). Although the characteristics of the project have been carefully described to respondents in a face-to-face interview and although the interviews were conducted two years after a major flood occurred in Roanoke, 15% of the respondents could not attach a monetary figure to the reduction in flood risk; another 25% refused to respond because they thought it unfair to ask those who suffered food related loss to have to pay for the project. If 40% are either not able to answer or express an attitude rather than value the project, the credibility of the answers of the remaining 60% is challenged. The authors themselves assert that, because of the complexity and unfamiliarity of the task, the interview process constructed preferences rather than eliciting existing preferences.

Similarly, the problem of strategic behavior can only be addressed to a limited extent. In a contingent valuation study of protective measures to prevent deathly avalanche accidents in

Tirole, Austria, Leiter and Pruckner (2005) find that the expressed *WTP* strongly depends on the perception of the own risk and, therefore, own benefits of protective measures. Even though respondents are asked to value an objective change in future risks, skiers and persons who perceive their own risk above average risk are willing to pay significantly more. As long as such confounding factors cannot be accounted for, the valuation of an objective change in risk is compromised.

The life satisfaction approach is not affected by either of these problems. It does not rely on respondents' ability to consider all relevant consequences of a change in the provision of a public good. It suffices if they state their own life satisfaction with some degree of precision. This considerably reduces the "informational and computational burden" on the subjects (Di Tella, MacCulloch and Layard 2002, p. 9). Moreover, there is no reason to expect strategic behavior because the connection between life satisfaction and the public good is made ex post by the researcher. Of course, one might argue that a respondent living in a polluted and terrorized region, anticipating that his reported life satisfaction is used to value air quality and national security, strategically reports an overly low life satisfaction. While theoretically possible, this problem is most likely to be of minor importance in practice. Life satisfaction data are usually collected for a multitude of purposes and the same data can be used to value a wide array of public goods. This effectively prevents strategic biases. At most, this theoretical possibility is a further argument against using life satisfaction data collected by questionnaires with extensive references to the public good of interest.

### 2.3.2 Revealed preference methods

This other group of non-market valuation techniques is based on the idea that, when choosing between different bundles of public and private goods, individuals make a trade-off, revealing something about the value they place on these goods. Under specific circumstances, this allows for inferences to be made about individuals' *WTP* for the public good from market transactions in the private good. The most prominent revealed preference methods are (i) the hedonic method, (ii) the travel cost approach, and (iii) the averting behavior method. These methods and their respective weaknesses are compared to the life satisfaction approach.

*Hedonic method*. The hedonic method can be applied if the public good is weakly complementary to private goods such as housing and jobs (for introductions see Palmquist 1991;

Freeman 2003, pp. 343-416; Taylor 2003).[11] This is the case, for example, if the (local) public good is a qualitative characteristic of the differentiated market good housing and of jobs. In this situation, the housing and labor market function as markets for the public good and information on public good demand is embedded in the prices and consumption level of private goods. People can choose their level of consumption of a public good by their choice of a jurisdiction in which to reside and work. The higher the value individuals attach to a particular public good, the more they will bid up house prices and bid down wages in regions with a high amount of the public good. Wage and rent differentials serve as implicit prices for the public good. In equilibrium they correspond to the individuals' marginal *WTP* (*MWTP*) for the public good (Rosen, S. 1974; Roback 1982).

The assumption that housing and labor markets are in full equilibrium is a first and fundamental difficulty of the hedonic method. This assumption is only met when households have a very high degree of information, when there is a sufficiently wide variety of houses and jobs, when prices adjust rapidly, when there are no market restrictions and when transaction and moving costs are low (Freeman 2003, p. 366). The equilibrium assumption is often violated. For example, moving is associated with considerable out-of-pocket and psychic costs. If mobility is costly, the true value of a change in the public good provision is greater than the house price effects imply. Consider the case of an exogenous improvement in air quality in a particular region. The cleaner air attracts new residents and, as a consequence, costs of housing rise until a new equilibrium is reached. Without mobility costs, the change in the costs of housing fully reflect the value of cleaner air. But if migration is costly, a person will only move to the region with improved air quality if the cleaner air compensates him or her for both, the higher rents and the cost of moving. In order to estimate the full *WTP* in presence of migration costs, Bayer, Keohane and Timmins (2006) develop an alternative discrete choice approach that models household decision directly and does not rely on the equilibrium condition. They use

[11] Exemplary contributions are Blomquist, Berger and Hoehn (1988) and Chay and Greenstone (2005). Blomquist, Berger and Hoehn (1988) estimate compensations for intra-urban and inter-regional differences in climatic, environmental and urban amenities in the labor and housing market for U.S. counties in 1980. According to their results, among the most important factors are central city status (annual *WTP* of $645 in 1980 U.S. dollars), whether the county touches an ocean or one of the Great Lakes (annual *WTP* of $468), the teacher-pupil ratio (annual *WTP* of $136 for a reduction of one pupil per teacher) and the number of designated hazardous waste sites (annual *WTP* of $106 per site). Chay and Greenstone (2005) investigate the effect of total suspended particulate (TSP) pollution and successfully address the identification issues hedonic method studies are usually plagued with. They find a marginal *WTP* (*MWTP*) of between $176 and $315 (in 2001 U.S. dollars) for a reduction of one $\mu g/m^3$ in TSP.

their approach to value air quality (total suspended particulate, TSP) in the U.S. metropolitan areas in 1990 and 2000. The estimated annual *MWTP* for the median household income amounts to between $149 and $185 (in 1983 U.S. dollars). By comparison, the *MWTP* estimated with the conventional hedonic model is only $55. The same problem can be viewed from a different perspective. If mobility costs restrict migration to the region with improved air quality, residents of that region who are not property owners get a rent. This rent is not reflected in the changes in aggregate property values. To recover residents' total *WTP* for the improvement in air quality, the rent has to be added to the changes in aggregate property values. Polinsky and Rubinfeld (1977) measure these rents by assuming a particular utility function and by interpreting the coefficients of the house and rent price regressions as parameters of the utility function. The approach is applied to value air quality (TSP and $SO_2$) in St. Louis, Missouri, in 1960. They estimate a total *WTP* for a reduction in air pollution by 5% of around $147 million (in 1960 U.S. dollars). In contrast, the total *WTP* implied in the changes in aggregate property values is only around $55 million. Thus, both studies suggest that conventional hedonic models underestimate the *WTP* for clean air by a factor of around three. In both studies, restrictive assumptions have to be imposed in order to estimate *WTP*. Nevertheless, the studies suggest that migration costs are important and that therefore the hedonic method may severely underestimate *WTP*. In contrast to the hedonic method, the life satisfaction approach explicitly captures utility in the absence of market equilibria. In the case of public goods for which it is useful to distinguish between expected benefits and materialized benefits and for which the effects on life satisfaction are identified on the basis of the latter, the life satisfaction approach can recover the full utility consequences independent of the degree of capitalization in the housing and labor market. For all other public goods, compensating variation in the private markets has to be accounted for. If they are not, the life satisfaction approach captures only the residual effect. These issues are discussed in more detail in section 2.4.2. Anticipating one of the main conclusions, the discussion suggests that, if anything, the life satisfaction approach works best if there is no market equilibrium.

Another drawback of the hedonic method is the need to account for adjustments people are likely to make in response to changes in the level of an externality, for reactions of the supply side of the hedonic market and for general equilibrium effects (see e.g. Pommerehne 1987, pp. 67-71; Freeman 2003, pp. 372-373).

*Travel cost approach*. As the hedonic method, the travel cost approach rests on the assumption of weak complementarity between public and private goods (for introductions see Clawson and Knetsch 1966; Freeman 2003, pp. 417-447; Parsons 2003).[12] But whereas in the hedonic method people are assumed to relocate with regard to regional differences in public goods, the travel cost approach rests on the premise that location decisions are driven by other factors. Instead, individuals spend time and money traveling to and consuming publicly provided goods, like recreational sites and cultural institutions. The travel cost approach takes advantage of the fact that each visit to a site involves an implicit transaction in which the costs of traveling to the site is incurred in return for access to the site. Hence, inferences about individuals' *WTP* for the site and site characteristics can be drawn by treating the cost of travel to the site as an implicit price. Variation in price is generated by observing individuals at different distances from a particular site and sites at different distances for any individual.

In contrast to the life satisfaction approach, the travel cost approach is only applicable if the consumption of the publicly provided good entails costs and is restricted to a small number of public goods. Further, in the case of the travel cost approach, the shadow price of time is critical to the evaluation of the public good, but inherently difficult to observe (Randall 1994). Finally, it is a central but equivocal assumption that travel serves no other purpose than the consumption of the public good and provides no utility or disutility in itself.

*Defense expenditure approach*. The defense expenditure approach can be applied if the consumption of private goods substitutes for the provision of public goods. For example, private expenditures for security measures may serve as a substitute for public security measures. Behind the simplest applications of the defense expenditure approach lies the assumption of perfect substitutability (Zeckhauser and Fisher 1976). An increase in public security measures then leads to a decline in private defense expenditures which in turn corresponds to an individual's *MWTP* for the increase in public security. While a substitutive relationship is often plausible, perfect substitutes represent a special case that is unlikely to prevail in many policy areas of interest (Pommerehne 1987, p. 25). Therefore, substitution is often modeled more generally in a household production framework. In this framework, the public and the private

[12] For an application of the travel cost model, see e.g. Hausman, Leonard and McFadden (1995). They estimate utility losses due to the Exxon Valdez oil spill like Carson et al. (2003), the latter study using contingent valuation surveys. The effect estimated with contingent valuation is more than 700 times higher than the one estimated with the travel cost approach.

goods simultaneously contribute to the production of a utility-yielding good such as health. The *MWTP* for the public good then typically is a function of the price for the private good and the marginal rate of technical substitution between the private and the public good (see Bartik 1988; Dickie 2003; Freeman 2003, pp. 105-110).[13]

Several conditions have to be met for the defense expenditure approach to reveal the correct *WTP*. First, the private good has to be a necessary input in the production of the utility-yielding good. Second, there should be no major costs involved with adjusting defense expenditures or averting behavior. Third, there must be no joint production in the sense that the private and public good jointly produce more than one good, nor in the sense that the private or public good contribute to utility directly in addition to their contribution to the utility-yielding good. If the public good has additional direct effects on utility, the *WTP* is underestimated. For example, *WTP* estimates that account only for the effects of the improvement in air quality on illness may disregard important effects such as reduced material damages and improved visibility. Finally, key parameters are often difficult to measure. For example, a reduction in the time spent outdoors is an effective and widely observed measure for individuals to defend themselves against air pollution-related health problems (Bresnahan, Dickie and Gerking 1997). The costs associated with these behavioral adjustments are typically unobserved. However, the unmeasured impact of poor air quality on daily life may represent a significant component of the value of clean air. Thus, these costs have to measured with other methods, above all with stated preference methods (e.g. Mansfield, Johnson and Van Houtven 2006).

The life satisfaction approach is affected by neither of these problems. The effect of a change in the public good provision on life satisfaction can be observed even if it entails no reaction in the consumption of a private good, be it because the private good is not an essential input in producing a utility-yielding good or because adjustment costs prohibit adjustments in defense

[13] Exemplary applications are Gerking and Stanley (1986) and Dickie and Gerking (1991). Both studies estimate the *WTP* for tropospheric ozone control in St. Louis, Missouri, and the Los Angeles metropolitan area, respectively. Further, both studies treat medical expenses as the private good that together with clean air prevents illness. Gerking and Stanley (1986) estimate an annual *WTP* of between $18 and $25 (in 1980 U.S. dollars) for a 30% reduction in ozone. These *WTP* estimates are relatively modest because due to the relatively clean air in St. Louis, the contemplated reductions are small. According to Dickie and Gerking (1991), individuals living in high ozone areas of Los Angeles are willing to pay over $170 (in 1985 U.S. dollars) annually for an environment in which ozone concentrations never exceed the U.S. federal standard of 12 pphm.

expenditures. Further, the direct effects of the private good and the public good as well as the utility costs of averting behavior are all reflected in life satisfaction.

*Perceived versus objective level of public good provision.* A problem common to all methods based on revealed preferences is that consumption and relocation decisions are based on perceived rather than objective (dis-)amenity levels. In case people's perceptions and objective measures do not correspond sufficiently, the estimates may be severely biased. This can be well demonstrated for the case of natural hazard risks. Brookshire et al. (1985) and Troy and Romm (2004) show that disclosure of information on natural hazard risks importantly influences price gradients in hedonic market analyses. Brookshire et al. (1985) compare the price gradients for earthquake safety in the Los Angeles and San Francisco areas before and after the Alquist-Priolo Act was passed in 1974 which provided the society with information concerning relative earthquake-associated risk by designating areas of elevated relative risk. Similarly, Troy and Romm (2004) compare price gradients on non-floodplain areas before and after the 1998 California Natural Hazard Disclosure Law. Both studies find no price differential between risky and safe areas before the laws have been passed, but large and significant price differentials thereafter. These results imply that estimates based on the hedonic method are severely biased downwards when individuals do not have access to objective information on risks. Theoretically, the direction of the bias when people lack statistical knowledge is not determined. Research on the availability heuristic suggests that people consider risks to be significant if they can easily think of instances in which those risks came to fruition (Kahneman, Slovic and Tversky 1982). Incidents of natural disasters may then cause people to exaggerate objective risks or, on the other hand, result in subjective risk perceptions that are unrelated to objective risks. The multi-facetted interactions between incidents of natural disasters and risk perception are documented in several hedonic market analyses. Driscoll, Dietz and Alwang (1994) and Bin and Polasky (2004) estimate larger price discounts in hedonic property price functions for houses located within a floodplain in the aftermath of a flood than before the flood occurred. In contrast, analyzing the same area as Brookshire et al. (1985), Beron et al. (1997) find that the price gradient for earthquake fell after the 1989 Loma

Prieta Earthquake, indicating that consumers had initially overestimated the earthquake hazard.[14]

The same caveat applies, to some extent, to the life satisfaction approach. This is the case if the perceived risk itself is the main source of utility loss. For example, if the fear associated with terrorism risks were the most important effect of terrorism, distorted risk perceptions could bias the result. This is not to say that terrorism risks may not have larger consequences than statistically comparable risks because of an additional fear or dread factor (Becker, G. S. and Rubinstein 2004). Both the life satisfaction approach and revealed preference methods would rightly capture such a broad risk assessment as a source of disutility. However, the life satisfaction approach and the revealed preference methods cannot measure fear effects which are totally unrelated to the underlying objective risk. The problem of revealed preferences methods is that individuals' behavior in private markets always reflects expected future risks (even if expectations are based on current or past risks). In contrast, in most applications of the life satisfaction approach, the utility consequences of risks are primarily identified on the basis of actual events, i.e. when the risk materializes. The life satisfaction approach is, therefore, less affected by distorted risk perceptions. A related strength of the life satisfaction approach is that it can capture indirect effects which leave no behavioral trace. For example, whereas noise nuisance affects utility directly and results in corresponding defense expenditures or relocation decisions, exposure to air pollution can damage health through a process unnoticed by the people, but which nevertheless lowers life satisfaction. Smith and Huang (1995) present evidence that is compatible with the hypothesis that health effects of air pollution are incompletely capitalized in housing markets. Benefit estimates for improvements in air quality in four U.S. cities based on dose-response functions and on Viscusi's (1993) summary value of mortality risk (mostly based on revealed preference methods!) are around four times higher

[14] Similar findings have been documented for hazardous waste sites. Kohlhase (1991) finds a positive relationship between the distance of a house to the next hazardous waste site and its price, but only after the U.S. Environmental Protection Agency (EPA) placed the site on the National Priorities List. To sites on the EPA list, a preliminary risk assessment is applied. Later the EPA releases an in depth Remedial Investigation. Gayer, Hamilton and Viscusi (2000; 2002) compare house price gradients before and after the release of the Remedial Investigation. According to their results, the negative effect on housing prices decreases (in absolute terms) after the release of the Remedial Investigation. The authors conjecture that the investigation provides risk information that lowers initially alarmist perceptions of the risk. The evidence suggests that prior perceptions are based on the national averages of risk levels at designated areas. Because the studied sites have below average risk levels, the investigation lowers risk perceptions. Further, according to several studies, risk perceptions are importantly influenced by newspaper publicity of a site (e.g. Gayer, Hamilton and Viscusi 2000; 2002; McCluskey and Rausser 2001).

than benefit estimates based on hedonic property studies. If people recognize the health effects of air pollution, these effects would be reflected in property prices in addition to a wide range of additional effects of air pollution. The life satisfaction approach captures health effects irrespective of whether people are aware of the causes or not.

*Decision versus experienced utility*. The standard methods, stated preference and revealed preference methods, are also challenged by the systematic divergence of the two concepts of utility, decision and experience utility (e.g. Kahneman, Wakker and Sarin 1997; Kahneman and Thaler 2006), or of "wanting" and "liking" (e.g. Camerer, Loewenstein and Prelec 2005). As welfare measures based on revealed preference methods and stated preference methods are measures of decision utility, they may be biased estimates of the hedonic experience of the decision as evaluated ex post by the individuals themselves. In the case of revealed preference methods, decisions in markets for private goods may not accurately reveal people's hedonic experience from the consumption of public goods. As Rabin (1998, p. 33) points out, "[t]he realization that decision and experienced utility may be systematically different cuts to the core […] of our methods of research, requiring us to formulate ways of inferring and eliciting preferences that go beyond a 'revealed preference' method […] through such methods as self reports of satisfaction […]." In the same vein, respondents to contingent valuation questions may not be able to make accurate predictions of the hedonic consequences of their (hypothetical) choice. In both, hypothetical and real markets, individuals may mispredict their future feelings due to a combination of incorrect intuitive theories about the determinants of happiness, incorrect believes regarding the speed and degree of adaptation, a difference in saliency of various aspects between the moment of prediction and the moment of experience and a focusing illusion (for a discussion of these effects in the specific context of contingent valuation surveys, see Loewenstein and Schkade 1999; Kahneman and Sugden 2005). If people underestimate future utility streams derived from intangible goods such as good health relative to utility streams from disposable income (Frey and Stutzer 2004a), *WTP* estimates based on the standard approaches fall short of the experienced utility consequences of the evaluated change in public good provision. Moreover, these deviations and discrepancies are most likely in complex decisions with long-term trade-offs (Camerer, Loewenstein and Prelec 2005), i.e. nearly all decisions of policy relevance.

## 2.4 Applications and identification issues

The preceding discussion suggests that the life satisfaction approach obviates several of the problems inherent in the standard methods. Its application instead of, or complementary to, the traditional methods therefore seems promising. The life satisfaction approach can be used to value a wide range of different public goods and bads, negative and positive externalities. However, as the following literature review illustrates, it has hitherto mainly been used to value externalities in the environmental realm. The literature review also highlights methodological differences between the applications. The differences have important implications regarding the identification of effects of the public goods on life satisfaction. Three identification issues are discussed in the following: the problem of omitted variables, compensating variation in private markets and the choice of spatial units across which the effects are identified. In a brief outlook on the three applications in the following chapters, we discuss how the applications relate to each other and how they address the three identification issues.

### 2.4.1 Previous literature

The goods with a public character that have been valued with the life satisfaction approach can be grouped into four broad categories: climatic conditions, air pollution, noise nuisance and crime.[15] The major results of the studies are summarized in table 3. The table depicts the coefficients for the public goods of interest and, for comparative purposes, the *WTP* for a marginal improvement in the public good provision and the elasticity between the public good and income. Only a few studies report one or both of these figures. Whenever possible, they have been calculated using the regression results and the information provided in the descriptive

[15] Several research areas are closely related to the valuing of public goods with data on subjective well-being. However, because they all differ in at least one important respect, they are not discussed here. First, several papers investigate the effect of *perceived* public good provision on life satisfaction such as concerns about ozone pollution and species extinction (Ferrer-i-Carbonell and Gowdy 2007) and perceived noise and air pollution exposure (Rehdanz and Maddison 2007). Second, subjective well-being data are used to monetize all kinds of intangible goods, life events and circumstances such as marriage, divorce, widowhood, social relationships, health, unemployment and having a black skin (e.g. Clark and Oswald 2002; Blanchflower and Oswald 2004b; Powdthavee 2007). Though these "goods" are not normally bought in markets, they have neither public good character (with associated free-rider problems) nor are they publicly provided. This method has also been proposed for calculating compensatory damages for the grief of dependents of a victim (Posner and Sunstein 2005) and for disability (Oswald and Powdthavee 2006, taking into account adaptation) in the context of tort-law. Third, another strand of literature assesses the life satisfaction consequences of voluntary contributions to public goods such as purchasing environmentally-friendly products, conserving water and contributing to environmental groups (Videras and Owen 2006), of volunteering (Meier and Stutzer 2007) and of informal care-giving (Van den Berg and Ferrer-i-Carbonell 2007). Finally, close in spirit is a paper by Kimball et al. (2006) estimating the short-run happiness consequences of natural disasters with high-frequency data.

statistics. The figures are only calculated for those public goods that have a significant impact on reported subjective well-being. Finally, they are calculated for the sample means of the relevant variables. In order to understand how to read the table, consider the first result reported in table 3, the results for the mean temperature in the hottest month. According to the study of Rehdanz and Maddison (2005), higher mean temperatures in the hottest month have a statistically significant negative effect on people's happiness. A person would be willing to pay up to $1,258 annually on average (corresponding to 7.50% of the average income; the *MWTP* is expressed in 2004 U.S. dollars) for a decrease of the mean temperature in the hottest month by 1˚C. Alternatively, if the mean temperature in the hottest month were to increase by 1%, income would have to increase by 1.56% to offset the utility loss.

*Table 3*. Major results of studies using the life satisfaction approach

| Studies, variables, coefficients and standard errors | | *MWTP* | Elasticity |
|---|---|---|---|
| *Climate* | | | |
| Study: Rehdanz and Maddison, 2005[a)] | | | |
| Dependent variable: 4-point happiness scale | | | |
| Regression coefficients: | | | |
| Mean temperature hottest month | -0.018 | $1,258 (7.50%) | 1.56% |
| | (0.009) | (for -1˚C) | (for +1%) |
| Mean temperature coldest month | 0.014 | $968 (5.78%) | 0.15% |
| | (0.005) | (for +1˚C) | (for -1%) |
| Mean precipitation wettest month | 4.E-4 | | |
| | (2.E-4) | | |
| Mean precipitation driest month | 0.001 | | |
| | (0.001) | | |
| *Air pollution* | | | |
| Study: Welsch, 2002 | | | |
| Dependent variable: 4-point happiness scale | | | |
| Regression coefficients: | | | |
| $SO_2$ concentration | 0.001 | | |
| | (0.001) | | |
| $NO_2$ concentration | -0.004 | $89 (0.69%) | 0.39% |
| | (0.002) | (for -1 $\mu g/m^3$) | (for +1%) |
| TSP concentration | 0.001 | | |
| | (0.001) | | |

*To be continued.*

*Table 3*, part 2

| Studies, variables, coefficients and standard errors | | *MWTP* | Elasticity |
|---|---|---|---|
| Dependent variable: ln(4-point happiness scale) | | | |
| Regression coefficients: | | | |
| ln($SO_2$ concentration) | 0.017 | | |
| | (0.012) | | |
| ln($NO_2$ concentration) | -0.450 | \$156 (1.22%) | 0.53% |
| | (0.025) | (for -1 μg/$m^3$) | (for +1%) |
| ln(TSP concentration) | -0.009 | | |
| | (0.025) | | |
| Study: Welsch, 2006[b)] | | | |
| Dependent variable: ln(4-point life satisfaction scale) | | | |
| Regression coefficients: | | | |
| ln($NO_2$ concentration) | -0.085 | | |
| | (0.053) | | |
| ln(TSP concentration) | 0.003 | | |
| | (0.039) | | |
| ln(lead concentration) | -0.020 | \$2,303 (8.28%) | 0.10% |
| | (0.008) | (for -0.1 μg/$m^3$) | (for +1%) |
| Dependent variable: ln(4-point life satisfaction scale) | | | |
| Regression coefficients: | | | |
| ln($NO_2$ concentration) | -0.057 | \$171 (0.61%) | 0.27% |
| | (0.025) | (for -1 μg/$m^3$) | (for +1%) |
| ln(lead concentration) | -0.012 | \$1,294 (4.65%) | 0.06% |
| | (0.005) | (for –0.1 μg/$m^3$) | (for +1%) |
| Di Tella and MacCulloch, 2005 | | | |
| Dependent variable: 3-point subjective well-being scale | | | |
| Regression coefficient: | | | |
| $SO_x$ emissions | -0.003 | \$156 (0.66%) | 0.32% |
| | (0.001) | (for -1 kg p.c.) | (for +1%) |
| *Noise* | | | |
| Van Praag and Baarsma, 2005 | | | |
| Dependent variable: 10-point life satisfaction scale | | | |
| Regression coefficient: | | | |
| ln(Kosten units) | -0.024 | | |
| | (0.025) | | |

*To be continued.*

*Table 3*, part 3

| Studies, variables, coefficients and standard errors | | *MWTP* | Elasticity |
|---|---|---|---|
| Dependent variable: 10-point life satisfaction scale | | | |
| Regression coefficient: | | | |
| ln(Kosten units) | -0.039[c)] | n.a. | 0.05% |
| | (0.012) | | |
| *Crime* | | | |
| Di Tella and MacCulloch, 2005 | | | |
| Dependent variable: 3-point subjective well-being scale | | | |
| Regression coefficients: | | | |
| ln(serious assaults per 100,000 people) | -0.029 | $27 (0.11%) | 0.32% |
| | (0.017) | (for -1 assault) | (for +1%) |

*General notes*: Standard errors are in parentheses. *MWTP*s and elasticities are estimated for mean values of the relevant variables. All *MWTP*s are in 2004 U.S. dollars.
*Specific notes*: a) Rehdanz and Maddison (2005) model the relationship between GDP p.c. and happiness as a quadratic function; both coefficients of the function are used although the one for the squared term is not statistically significant; b) Specifications with and without a variable for TSP concentration reported in Welsch (2006) are shown here; c) This coefficient is the product of the partial correlation between life satisfaction and perceived noise ($\alpha$) and the partial correlation of perceived noise and ln(Kosten units) ($\beta$); the standard error is estimated on the basis of Sobel's (1982) first-order approximation, $(\alpha^2\sigma_\beta^2 + \beta^2\sigma_\alpha^2)^{0.5}$.
*Source*: Results reported in studies and own calculations.

*Climatic conditions*. In a pioneer study, Frijters and Van Praag (1998) estimate the effect of several climate variables on life satisfaction for Russia in 1993 and 1994. They combine cross-section data for around 4,500 individuals with detailed information on the climatic conditions on the basis of 35 Russian climate regions. Unfortunately, several problems make it impossible to draw any firm conclusions. First, the regression includes several climate variables in the interaction terms without also including the direct effects of these variables. Therefore, several coefficients may be biased and difficult to interpret. Second, the study does not provide information on the mean values of the variables. Hence, no *WTP* can be estimated. Further, because most climate variables (also) appear in interaction terms and because mean values are not known, it is not possible to calculate elasticities. Third, the authors report the *WTP* for three variables in percent of income. However, these *WTP* estimates include the effect of the climate variables on income (estimated in separate hedonic wage regressions) weighted by the marginal effect of income. As the regression controls for income and, hence, is able to recover the full effect of climate on well-being, the indirect effect through income is double counted. Finally, although the climate variables are merged to the individual observations on the basis of climate regions, standard errors are (presumably) not adjusted for clustering on the regional level. Ignoring clustering produces standard errors that are biased downward (Moulton 1990).

No better verdict can be reached for two recent studies on the effect of intra-country climate variations on life satisfaction. For a cross-section of around 1,500 individuals in Ireland in 2001, Brereton, Clinch and Ferreira (2006) and Ferreira, Moro and Clinch (2006) estimate the effect of climate and a wide range of potentially interesting public goods on life satisfaction. In addition to five climate variables, Brereton, Clinch and Ferreira (2006) include 10 variables capturing aspects of the location of residence, access to services and urban amenities and dis-amenities, and Ferreira, Moro and Clinch (2006) include 13 variables for locational aspects, access to services and urban amenities and disamenities as well as two environmental variables. These aggregate data are merged to the individual data on a highly disaggregated level. The problem, however, is that the results completely lack robustness. A comparison of the two studies reveals that the sign and significance of the coefficients are extremely sensitive to the specification: Four of the five coefficients of the climate variables included in both studies change sign, and none retains sign and significance across the two studies. Similarly, two coefficients of the five locational variables included in both studies change sign and, again, none retains sign and significance across both studies.

Rehdanz and Maddison (2005) analyze the effects of climatic conditions on happiness on a global scale in a cross-section of 67 countries with observations from the years 1972 to 2000.[16] As shown in table 3, climatic conditions are captured by four variables: mean temperatures in the hottest and in the coldest month and mean precipitation in the wettest and driest month, respectively. The results suggest that people prefer higher mean temperatures in the coldest month and lower temperatures in the hottest month. The precipitation variables are individually and jointly insignificant. The authors use the regression results to calculate the change in real GDP per capita necessary to hold happiness constant at its current levels in the face of predicted changes in climate. According to their results, predicted climate changes decrease happiness in most countries. Only a few countries in high latitudes such as Canada, Finland, Iceland, Norway and Sweden as well as some Eastern European countries such as Azerbaijan, Georgia and the Ukraine are predicted to gain. Of course, these calculations are sensitive to the climate change predictions.

[16] Their sample includes 185 observations, i.e. around 2.8 observations per country on average. In order not to inflate the significance of the results and in order not to give countries with more observations undue weight, they use sample weights and adjust the standard errors for clustering on the country level.

*Air pollution*. Three studies assess the effect of air pollution on subjective well-being. In a cross section of 54 countries with observations from the early and mid 1990s, Welsch (2002) estimates the effect of four air pollutants and two water pollutants on happiness.[17] In a linear specification, only $NO_2$ and phosphorus pollution have the expected negative sign, which is significant for $NO_2$. The other pollutant coefficients are positive and insignificant. The same pattern of results emerges if the pollutants are included individually; it is therefore not caused by multicollinearity among the pollutants. In the double-log models, the coefficients for all pollutants except for $SO_2$ are negative, but in most cases insignificant (see table 3). The *MWTP* for a reduction of one $\mu g/m^3$ $NO_2$ amounts to between \$89 and \$156 (in 2004 U.S. dollars).[18] The negative effect of $NO_2$ is only partially corroborated in a repeated cross-section analysis for 10 European countries in the years 1990 to 1997 (Welsch 2006). In a regression of happiness on $NO_2$ and lead concentration, both pollutants have a statistically significant negative effect, whether they are separately or jointly included. However, as can be seen from table 3, the negative effect of $NO_2$ falls below conventional levels of significance if TSP is included as an additional pollutant. In contrast to the cross-county analysis (Welsch 2002), multicollinearity between pollution variables seems to be a problem in the repeated cross-section analysis (Welsch 2006). The implicit *MWTP* for $NO_2$ calculated with the significant coefficient lies in the range of the *MWTP* estimates found in the cross-section analysis.

Di Tella and MacCulloch (2005a) also use repeated cross-section analysis to investigate the effect of air pollution among a number of other factors. The analysis spans 23 years and 12 countries, 11 European countries and the United States. They find that sulfur oxides ($SO_x$) emissions have an adverse effect on subjective well-being that is significant. Moreover, interaction terms suggest that the adverse effect is larger (in absolute terms) for the young, a result that is compatible with the hypothesis that negative effects of a bad environment are more strongly felt by the young. Unfortunately, their indicator of "pollution" is highly prob-

[17] In a recent paper, Welsch (2007) extends the analysis in a conceptually interesting way. Replicating one of the earlier results, he regresses happiness on $NO_2$ concentration and GDP per capita and calculates the marginal monetary benefits of pollution abatement. Furthermore, he estimates a production function for per capita GDP in which air pollution plays the role of a "quasi-input" in addition to physical capital per capita and the number of scientists and engineers per capita as a measure for human capital. In this way, the marginal product of pollution – which is equal to the marginal cost of abatement in this framework – can be discovered. By equating the marginal benefits and costs of abatement, optimal abatement rates can be calculated.

[18] Welsch (2002) asserts that his air pollution data are measured in kilotons. However, according to later editions of the data used by Welsch (2002), pollution is measured in $\mu g/m^3$ (see Yale Center for Environmental Law and Policy 2002).

lematic. At the country level, emissions and pollution concentration are only weakly correlated. For example, only 14% of the Danish sulfur emissions remain in Denmark. For larger countries the fraction is higher, but below 50% for all European countries (Eliassen and Saltbones 1983).

*Noise nuisance*. Van Praag and Baarsma (2005) investigate the effect of airport noise nuisance on life satisfaction in a cross-section sample of 1,400 persons living in the area around Amsterdam Airport (Schiphol). High-resolution noise data are added to the individual-level data; noise is measured in Kosten units (named after a Dutch professor). The measure of objective noise nuisance has a negative effect on life satisfaction. However, this effect is not statistically significant. This result even holds for individuals living in houses without noise insulation (the first coefficient of the study reported in table 3). Van Praag and Baarsma (2005) conjecture that life satisfaction is influenced by perceived rather than objective noise levels. Further, the intervening variable perceived noise depends not only on objective noise levels but also on characteristics of the household and the house such as family size, the presence of a balcony or garden etc. Therefore, they estimate in two separate regressions the effect of objective noise levels on perceived noise and the effect of perceived noise on life satisfaction. Objective noise is indeed a significant predictor of perceived noise and perceived noise of life satisfaction. Thus, they calculate the effect of objective noise levels on life satisfaction as the product of these two effects (second coefficient of the study reported in table 3).

*Crime*. The study of Di Tella and MacCulloch (2005) includes an indicator for the crime level in a country and year. It is the natural logarithm of the number of serious assaults per 100,000 persons. As expected, the crime rate has a negative and statistically significant effect on life satisfaction (see table 3).

Overall, the literature review suggests that the level of public good provision is reflected in self-reported subjective well-being and that data on subjective well-being can thus be used to value public good. Further, the results summarized in table 3 indicate that the life satisfaction approach can provide important insights into many different areas. From a methodological perspective, the studies differ along two dimensions: A first dimension is the structure of the individual level data used. Most studies use single cross-sections. Exceptions are Di Tella and MacCulloch (2005a) and Welsch (2006). A second dimension is the degree of spatial resolu-

tion of the public good variables. While Welsch (2006), Di Tella and MacCulloch (2005a), Rehdanz and Maddison (2005) and Welsch (2006) use variables at the country (or country-year) level, Frijters and Van Praag (1998), Van Praag and Baarsma (2005), Brereton, Clinch and Ferreira (2006) and Ferreira, Moro and Clinch (2006) use high-resolution data. Both differences have important implications for the identification of effects of public goods on subjective well-being.

### 2.4.2 Identification of utility consequences

In the following, three identification issues are discussed: the problem of omitted variables, compensating variation in private markets and the choice of spatial units across which the effects are identified. It is important to note that two of these issues, the omitted variable problem and the degree of spatial resolution, are not restricted to the life satisfaction approach but apply equally to revealed preference methods.

*Omitted variables*. The life satisfaction approach is not immune to possible spurious correlations that are the result of omitted variables. As a concrete example consider air pollution. Imagine that people in polluted areas report on average a lower life satisfaction than their counterparts in areas with clean air. Obviously, the regions differ from each other in various ways other than the level of air pollution which are likely to influence the life satisfaction of their residents. Differences in air pollution reflect either different natural or economic conditions such as climate, population density, urbanization and the economic structure or different policy choices. A failure to control for the differences in conditions may bias the estimates in either direction. The notion of choice implies that a failure to include all dimensions of the relevant trade-off biases the estimates downwards. Improvements in air quality often come at a cost. If these costs are not controlled for, only the net benefit of clean air can be recovered.

There are three ways of addressing this problem. First, the problem can be mitigated by using data with panel structure, since the problem of omitted variable is especially severe in cross-section analyses. That cross-section analyses are susceptible to spurious correlations is well illustrated by the fact that six out of ten coefficients for the variables included in the studies of Brereton, Clinch and Ferreira (2006) and Ferreira, Moro and Clinch (2006) change their sign across different specifications. Data with panel structure allow researchers to control for time-invariant region- or country-specific differences in life satisfaction as well for area-indepen-

dent variations over time. Still, there may be time-variant regional effects that are correlated with life satisfaction and the variable of concern. This is particularly likely if the changes in public good provision are themselves endogenous. For example, a change in air pollution indicates that either conditions or policies have changed as well. Therefore, a second key issue is to control for potentially collinear variables. However, the lack of adequate indicators often limits this procedure. The third, and often the only, way to address endogeneity and simultaneity problems is to instrument the variance in the public goods provision.

*Compensating variation*. For a large number of potentially omitted variables, fixed effects, time-varying control variables and instruments are effective remedies. However, one particular group of potentially omitted variables requires further discussion: compensations in private markets, above all in the housing and the labor markets. According to the premise of the hedonic method, individuals exposed to public bads or negative externalities are compensated in these private markets. The markets compensate individuals for the costs of self-protection measures, for the costs of locally financed public measures as well as for any direct utility costs associated with these measures, for higher risk premiums for insuring themselves against damages as well as for all non-insurable and non-avertable losses. Similarly, public goods are thought to be bought in these hedonic markets. Therefore, this compensating variation has a countervailing effect on life satisfaction. The countervailing effect of the compensating variation has led to some confusion in the literature as to what part of the utility effects can be identified with the life satisfaction approach and to confusion on the relationship between the life satisfaction approach and the hedonic method (for opposite positions, see e.g. Van Praag and Baarsma 2005; Brereton, Clinch and Ferreira 2006).

In the standard hedonic method framework all public goods and bads are capitalized in rents and wages. In the standard framework, individuals are assumed to have an indirect utility function, $v(\cdot)$, with the amenity $a$, household income, $m(a)$, and rental costs, $r(a)$, per unit of housing, $h$, as arguments (with $\delta v/\delta a > 0$, $\delta v/\delta m > 0$ and $\delta v/\delta r < 0$). In the market equilibrium, wages and rents must adjust to equalize utility across locations (see e.g. Roback 1982). This does not mean that the positive effect of a public good would not affect residents' well-being. It is just that the positive effect is equally distributed among the residents of different locations. Otherwise, some individuals would have an incentive to move. Hence we have $v(a, m(a), r(a)) = k$ in all locations. By totally differentiating and rearranging we obtain:

(1) $$dv/da = \delta v/\delta a + \delta v/\delta m \cdot dm/da + \delta v/\delta r \cdot dr/da = 0.$$

Defining the implicit price for the amenity reflected in the labor and housing markets, $p_a$, as $p_a = h \cdot dr/da - dm/da$ and using Roy's (1947) identity, $h = -(\delta v/\delta r)/(\delta v/\delta m)$, one can write:

(2) $$p_a^* = h \cdot dr/da - dm/da = (\delta v/\delta a)/(\delta v/\delta m).$$

Thus, in equilibrium, the implicit price for the amenity equals the *MWTP*. This is the underlying assumption of the hedonic method. If the equilibrium condition holds, individuals' *MWTP* for the amenity can be inferred from the observable demand for residential housing as well as from rent and wage gradients. As discussed in section 2.3.2, various restrictions, moving and transactions costs as well as cognitive biases are likely to prevent complete equalization in reality. Moreover, landowners (and employees with firm-specific investments) only have a costly exit option from locations that are negatively affected by a public bad or an externality. If the labor and housing markets are not in equilibrium, utility is not equalized across locations with different amenity levels, i.e. $dv/da > 0$, and the observed implicit price falls short of individuals' *MWTP*:

(3) $$p_a = h \cdot dr/da - dm/da = (\delta v/\delta a)/(\delta v/\delta m) - (dv/da)/(\delta v/\delta m) < (\delta v/\delta a)/(\delta v/\delta m).$$

As explained in section 2.1, the life satisfaction approach does not rely on observed behavior but regresses life satisfaction, as an empirical approximation for the underlying latent variable utility, on the amenity level, income and other covariates. The coefficients for the public good and for income are interpreted as the marginal utilities of the public good and income, respectively, and the *MWTP* is calculated as the ratio of the marginal utilities. Brereton, Clinch and Ferreira (2006) assert that the life satisfaction approach and the hedonic method are *substitutes* because both methods yield exactly the same results if labor and housing markets are in equilibrium, but only the life satisfaction approach yields the theoretically correct result if the markets are not in equilibrium. However, this conclusion is wrong. In a regression of life satisfaction on the amenity level, the coefficient for the amenity level corresponds to the term $dv/da$ in equation 1. As can be seen, the coefficient equals the marginal utility if and only if either wages and rents are held constant or if the amenity is not capitalized in private markets,

i.e. if d$m$/d$a$ = d$r$/d$a$ = 0.[19] In general, rental costs are not in the set of explanatory variables in micro-econometric life satisfaction functions.[20] Thus, the coefficient for the amenity captures only the residual effect that is not capitalized in the housing market, i.e. d$v$/d$a$ = $\delta v/\delta a$ + $\delta v/\delta r$ · d$r$/d$a$ (< $\delta v/\delta a$). This same conclusion is drawn by Van Praag and Baarsma (2005). The residual effect is not capitalized in the housing market either because it is already capitalized in the labor market or because the housing market is not in equilibrium. The residual effect can be monetized with the marginal utility of income as shown in equation 4:

$$(4) \qquad (dv/da)/(\delta v/\delta m) = [\delta v/\delta a + \delta v/\delta r \cdot dr/da]/(\delta v/\delta m).$$

The sum of the implicit hedonic price in equation 3 plus the residual shadow benefit in equation 4 yields the correct *MWTP* for the amenity. Hence, the two methods are *complements*. The life satisfaction approach is applied to the best advantage when there is no, or only little, compensation in the housing market. In these situations, the hedonic method breaks down. In contrast, the life satisfaction approach works well.

It is tempting to see compensations in the housing market as the reason behind the difficulty of Van Praag and Baarsma (2005) to find a (statistically significant) negative effect of noise nuisance on life satisfaction. After all, the effect is identified in a relatively small urban area where transaction and moving costs are low. However, contrary to expectations, Van Praag and Baarsma (2005) find no negative effect of noise nuisance on housing prices.[21] The problem of countervailing compensating variation is probably less severe if the effects on life satisfaction are identified across large distances where the assumption of unhindered mobility becomes untenable as in cross-country analyses.

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[19] If amenities are capitalized in private markets and life satisfaction is regressed only on the amenity level but neither wages nor rents, a mis-specified model of the form $v = \widetilde{\beta}_0 + \widetilde{\beta}_1 a + \varepsilon$ instead of the true population model $v = \beta_0 + \beta_1 a + \beta_2 m + \beta_3 r + \varepsilon$ is estimated. The coefficient $\widetilde{\beta}_1$ is a biased estimate of $\beta_1$ and amounts to $E(\widetilde{\beta}_1) = \beta_1 + \beta_2 \sum((a_i - \overline{a})m_i)/\sum(a_i - \overline{a})^2 + \beta_3 \sum((a_i - \overline{a})r_i)/\sum(a_i - \overline{a})^2$, which corresponds to d$v$/d$a$ in equation 1.

[20] Even if housing rents are available in the data, it may not be advisable to include them in life satisfaction regression because it is not possible to control for all relevant observed and unobserved housing characteristics.

[21] This can be explained by an over-regulated housing market and by the fact that Shiphol Airport has the obligation to insulate houses in the most exposed residential quarters at no cost to the population. Hence, noise nuisance is not compensated but rather removed to a large extent.

So far, the analysis refers to cross-section analyses. In order to see how compensating variation affects the identification of utility effects in repeated cross-section and panel analyses, it is helpful to differentiate between two types of public goods. The first type of public goods, or rather public bads, are risks, i.e. public bads occurring with a certain probability. The second type is a residual category of all other public goods. In the case of risks, compensating variation in the housing market is based on expected risks. If the underlying probabilities are stable, the compensating variation is captured by the region-specific effects. By the same token, all utility costs of insurance, protection measures and self-protection measures are reflected in the fixed-effects. In applications of the life satisfaction approach with repeated cross-section or panel data, the effect of risks are identified on the basis of actual events, i.e. if the risk materializes. Therefore, the full utility losses or, more precisely, the full non-insurable and non-avertable losses can be recovered. In this situation, the hedonic method and the life satisfaction approach are *substitutes*. However, this is not the case for public goods for which it is not meaningful to differentiate between expected and materialized risk. Assuming that not all future changes in the public good provision are expected and capitalized in the housing market, utility will be equalized across regions at every point in time but not necessarily across time.[22] The changes over time, however, are captured in the year fixed effects. Thus, even with repeated cross-section and panel data, only the residual effect can be captured. Of course, compensation is most likely to be minor in a panel setting in which annual intra- and interregional fluctuations are studied. In this context, the residual effect may capture a great part of the overall utility effects of the public good considered. Nevertheless, conceptually, it is still a residual effect and the two methods remain complements.

*Spatial resolution.* A critical element of the analysis is the choice of spatial units or regions across which changes in life satisfaction are identified. Two separate problems are associated with this choice. First, the geographical extension of the externality has to be established. Second, one has to decide at what level of spatial disaggregation data on public goods are collected and merged to the individual-level data.

For externalities that are entirely physical in nature, in particular externalities in the environmental realm, the determination of the geographical boundaries poses no problem on the con-

[22] It is important to note that while future changes in amenities may be capitalized into sales prices, they are not expected to be capitalized into current rents (see Taylor 2003).

ceptual level. For example, the concentration of air pollutants can be measured at each location and the geographical extension of a flood disaster can be accurately assessed. However, respondents' exact place of residence is usually not known, either because the information has not been collected or because it is not disclosed for privacy reasons. Therefore, data on the public good and data on life satisfaction have to be matched on the basis of administrative boundaries. The choice of the level at which the data are merged influences the identification of utility effects. For example, if all individuals affected by a flood disaster are expected to suffer similar losses, i.e. if the externality can be adequately described by an indicator function, the average treatment effect of the flood is underestimated whenever the administrative boundaries do not match the geographical extension of the flood perfectly. Some respondents are wrongly assigned to the reference group, i.e. categorized as not being affected even though they live in the flooded area, others are wrongly counted among the victims. Because the treatment group is usually much smaller compared to the reference group, the second type of error carries more weight. In general, therefore, it is better to err on the side of setting the boundaries too narrow. This conclusion does not necessarily apply if people living near a major river in the center of the flooded area are hit more severely than people living near tributaries at the periphery of the flooded area, i.e. if the externality is better described by a general function of distance from the center. In this case, the direction of the bias is not determined. Of course, this problem could be averted by modeling the function of distance or by using detailed data on the severity of the flood at each location. Objective measures at each location are usually possible for externalities such as air pollution and noise nuisance. Aggregating this information on the level of administrative units thus introduces an additional measurement error. This measurement error increases with the size of the chosen units. As it is well known, such a measurement error entails an attenuation bias. As discussed in section 2.4.1, Welsch (2002; 2006) and Di Tella and MacCulloch (2005a) investigate the effect of air pollution on subjective well-being with country-level data. Because of the huge variation in the air quality within countries, country-level data are a very imprecise measure of individuals' exposure to air pollution. Thus, the coefficients for the pollutants are likely to be biased towards zero.

In contrast to externalities of a physical nature, drawing the boundaries of the externality is far more difficult for social externalities, like externalities of education, cultural amenities, crime or terrorism. Terrorism, for example, is explicitly "conceived to have far-reaching psychologi-

cal repercussions beyond the immediate victim or target" (Hoffman, B. 1998, p. 38; Wilkinson 2000, p. 12, among others). Again, the estimated effect will therefore crucially depend on the spatial unit chosen. Suppose, for example, a bomb explodes in the crowded centre of a small Northern Irish town and kills a large number of civilians. This terrorist incidence can affect people's well-being in very different ways. It could be taken as an indication of a new wave of terrorist attacks all over the British Isles and the atrocity could shock people everywhere alike. In that case, it is quite likely that the life satisfaction is depressed everywhere in Great Britain and in Northern Ireland to the same extent. The effect of the incident on individuals' well-being then cannot be identified across these two regions. If, on the other hand, only people in Northern Ireland are affected by an incident taking place in Northern Ireland and no spillovers occur, the average decrease in life satisfaction due to terrorism can be fully identified. In many cases, reality is characterized by an intermediate case, whereby individuals living in Great Britain (or any other region not immediately affected by an event) are also affected, but to a lesser degree. Only the difference from the average impact, which the event has in the two regions, can be identified. These simple examples should convince the reader that an accurate definition of the region across which the utility loss is identified is essential. There is no general solution to this problem. The choice must be guided by knowledge of the actual situation. Moreover, if possible, the sensitivity of the results to alternative definitions of the regions should be assessed.

*Summary of identification issues.* The preceding discussion of the three identification issues makes clear that in most situations, a combination of data with panel structure and high-resolution data on the public goods is the most promising approach to identify the full utility consequences. To our knowledge, in none of the previous applications both features of the data are simultaneously present. However, all applications in the following chapters will be based on this combination. In addition, the life satisfaction approach is best applied to situations where compensation in the housing market is unlikely or to the evaluation of public goods where it is sensible to differentiate between expected and materialized risks. If such a differentiation is not sensible and compensation is likely, the life satisfaction approach should be supplemented with a hedonic housing study.

### 2.4.3 Outlook on own applications

In the following three chapters, the life satisfaction approach is used to assess the effects of air pollution, flood disasters and terrorism. In public debate and the political process, these public bads rank among the most important and permanent issues. Further, they can be expected to remain top priorities in the near future. Thus, the relevance of the three public goods makes an assessment of the utility consequences for the affected population important in its own right. The weight of these public bads in the public debate and political process also suggests that they may indeed significantly reduce the well-being of the affected population (see chapter 1 and the introductory sections of the following chapters for evidence on the relevance and potential effects of the three public bads). This makes it more likely that the consequences can be statistically detected in the life satisfaction data. Arguably, the life satisfaction approach with currently available subjective well-being data is ill-equipped to assess minor impacts of secondary public goods. Despite their shared importance, the nature of the three public bads greatly differs. Hence, the applications also illustrates that the life satisfaction approach can be applied to a wide variety of questions and issues.

All three applications address the identification issues discussed in the preceding section. In all applications, we use data with a panel structure and are thus able to control for region- and time-specific omitted variables. We also try to control for potential time-variant regional effects that are correlated with life satisfaction and the public good variables. For example, in the case of terrorism, unemployment among young men and a general lack of opportunities during an economic downturn could further the recruitment of terrorist groups and simultaneously depress life satisfaction in the affected regions. In all applications, therefore, we check the robustness of the results to the inclusion of fundamental macro-economic variables. Simultaneity problems are even more acute in the case of air pollution (see e.g. Chay and Greenstone 2005; Bayer, Keohane and Timmins 2006). While technical progress and air quality regulations are important reasons for improvements in air quality, local economic downturns and declining industrial production are other likely candidates. These temporally and spatially coincident developments have a countervailing effect on life satisfaction. To avoid this potential source of bias, we construct a novel instrument exploiting the natural experiment created by the mandated scrubber installation at power plants, with wind directions dividing regions into treatment and control groups.

As with the simultaneity problem, the issue of compensating variation in the housing market is most likely to be important in our application of the life satisfaction approach to air pollution in Germany. The effect of air pollution is identified at a spatially highly disaggregated level, the level of German Kreise. At this level of disaggregation, migration costs can be assumed to be comparably low. Further, by international standards, the German housing market is relatively loosely regulated (Hoffmann and Kurz 2002). Therefore, the life satisfaction approach is supplemented by a hedonic housing analysis. In contrast, in the case of terrorism, the effects on life satisfaction are identified on the basis of larger geographical areas. This makes migration and, hence, compensation in the housing market a less pressing issue. Nevertheless, evidence presented in chapter 5 shows that people do migrate in response to terrorist activity. Thus, some compensating variation in the housing market cannot be ruled out completely. As discussed in section 2.3.2, compensations in the housing market are no concern in the application to flood disasters. Price differentials in the housing market are based on the expected risk of floods, the effect on life satisfaction is identified when this risk comes to fruition.

All applications are based on existing survey data. Therefore, in none of the applications respondents' exact location of residence is known. In order to minimize measurement errors and a wrong assignment of respondents into the treatment group rather than into the control group, spatially highly disaggregated data are used in the applications to air pollution and flood disasters. In the former case, the pollution data are aggregated on the level of German Kreise. The GSOEP, the data source on which the application is based, is not available on a higher spatial disaggregation for users working outside the DIW in Berlin. Similarly, in the case of flood disasters, the survey and the flood data are matched on the lowest geographical level that ensures a consistent definition across countries and over time. For Europe, this is the middle level of the official statistical units of the EU, the NUTS II regions, for the United States it is the county level. In the case of terrorism, choosing the right spatial resolution involves the additional difficulty of correctly determining the geographical extension of the public bad. The choice depends on the nature of the conflicts in these countries. For both, France and the British Isles, it seems reasonable to distinguish three regions. The pattern of terrorist activity is relatively homogenous within but different across these regions. In the case of France, the regions are Ile-de-France (which includes Paris), Provence-Alpes-Côte d'Azur (including Corsica) and the rest of France. Many terrorist incidents are clearly confined to Paris. The city was

plagued by attacks on foreign ambassadors, other diplomats and government officials, as well as the headquarters or domestic branches of firms. Similarly, most attacks of the *Front de Libération Nationale de la Corse* (FLNC) were perpetrated in Corsica rather than in continental France. In the case of the United Kingdom and the Republic of Ireland, the three regions are Northern Ireland, Great Britain and the Republic of Ireland. The pattern of terrorist activity clearly differs across these regions. Even though republican groups carried the conflict to Great Britain, Northern Ireland experienced violence on a much larger scale. Loyalist groups such as the *Ulster Volunteer Force* (UVF), its splinter group the *Loyalist Volunteer Force* (ULF) and the *Ulster Defence Association* (UDA) limited their activity largely to Northern Ireland. In contrast to France, London has no special position with respect to terrorist activity (at least in case of terrorist activity related to the Northern Ireland conflict). For example, the attacks with the highest death toll recorded in a single day occurred in Birmingham rather than in London (Birmingham pub bombings of 1974). In order to test the sensitivity of the results to the choice of spatial resolution, the analysis is replicated with data on a smaller scale.

One further methodological difference between the applications requires discussion. The application to flood disasters is based on the Euro-Barometer Survey Series (EB) and the U.S. General Social Survey (GSS) and the application to terrorism is based on the EB. Both surveys interview a cross-section sample each year. In contrast, the GSOEP is a panel at the individual level. Moreover, the GSOEP contains a wealth of information on respondents unparalleled by the EB. Both features of the GSOEP allow us to address endogeneity and omitted variable problems which are particularly relevant in connection with estimating the effect of income on life satisfaction.

*As soon as I escaped from the oppressive atmosphere of the city, and from the stink of the smoky chimneys, which, being stirred, pour forth, along with a cloud of ashes, all the poisonous fumes they've accumulated in their interiors, I perceived at once change in my feelings.*
Seneca, epistle CIV

## 3. Application to air pollution

### 3.1 Introduction

The introductory quote by Seneca demonstrates that urban air pollution was already a menace in first century Rome. Yet it was the twentieth century that witnessed both the worst air quality and massive improvements. Air pollution could be literally seen and felt, causing the first manmade climate change (a drop in temperature caused by sulfur particles bouncing back sunlight), occasionally forcing motorists to turn headlights on or leave their cars because of impaired visibility, damaging historic buildings (e.g. Time 1967; Economist 2006), and, most importantly, increasing morbidity and mortality (see references below). In response, many countries enacted air quality regulations such as the Clean Air Act in the United States characterized by some scholars as the most significant laws aimed at advancing environmental quality, safety and health (Portney 1990), these regulations brought about considerable improvements in air quality. However, the pollution situation does not look bright in all countries nor for all pollutants. This raises the questions of how important air quality is for the affected population and, consequently, about realized and potential benefits of air quality regulations.

Traditionally, the benefits of clean air have been mostly assessed with the hedonic method (see Smith, V. K. and Huang 1995 for a meta-analysis). However, as discussed in section 2.3.2, migration costs and market disequilibria, individuals' partial ignorance of the effects of air pollution and the divergence of decision and experienced utility all suggest that effects of air pollution experienced by the affected population are incompletely capitalized in private markets. Section 2.4.2 shows that the life satisfaction approach can capture the residual effect of air pollution for which people are not already compensated in the housing market. If all effects of air pollution are correctly perceived and the equilibrium condition holds, air pollution should not be systematically related to life satisfaction. Thus, the life satisfaction approach also allows us to directly test the fundamental assumptions of the hedonic method and

to assess the importance of deviations from these assumptions. This chapter has two major objectives. First, we estimate the effect of $SO_2$ concentration on life satisfaction and housing rents for Germany, a country with a large variation in pollution, both across space and over time. Second, using the results of the life satisfaction regressions and of the hedonic housing regression, we calculate the total *WTP* for improvements in air quality as the sum of the estimates based on the two different methods. A comparison of the estimates based on the two different methods also reveals what part of the total effect is capitalized in private markets.

We concentrate on $SO_2$ pollution for three reasons. First, for a long time, $SO_2$ was one of the major pollutants in industrialized countries and the primary focus of many regulations. Second, the main emitters of $SO_2$ are large stationary sources. Taken together, these characteristics give rise to a large variation in $SO_2$ concentrations, both across regions and across time. Third, $SO_2$ contributes to the formation of acid rain, impairs visibility and, most importantly, causes adverse health effects. Consequences of $SO_2$ exposure found in controlled laboratory studies are bronchoconstriction, decrements in respiratory functions, mucus secretion, alterations in pulmonary defenses and airway inflammation with consequent coughing, wheezing, shortness of breath and chest tightness (Sheppard et al. 1980; Sandstrom et al. 1989; Smith, E. G., Haines and Stone 1994). According to epidemiological studies, high $SO_2$ concentrations result in increased morbidity and premature mortality due to cardiovascular and respiratory diseases (Schwartz, J. and Dockery 1992; Wong et al. 1999).

## 3.2 Air pollution: Data, pattern and instrument

The *Umweltbundesamt* (German federal environmental agency; hereafter UBA for short) provides data on the annual mean $SO_2$ concentration measured at the monitors belonging to the monitoring networks of the 16 *Landesumweltämter* (state environmental agencies) and the UBA for the years 1985 to 2003. We have $SO_2$ data from 553 monitors or, in individual years, between 196 monitors in 1985 and 416 monitors in 1994. Panel A in figure 1 depicts the location of the monitors used for 1985. In order to estimate the $SO_2$ concentration at all other locations, we use a geographic information system (GIS) to interpolate the monitor readings on a grid with cell size of 1 $km^2$ covering the whole area of Germany. We estimate the value of cell *i* of the grid as the weighted average over the readings at the 9 nearest monitors *j* using the

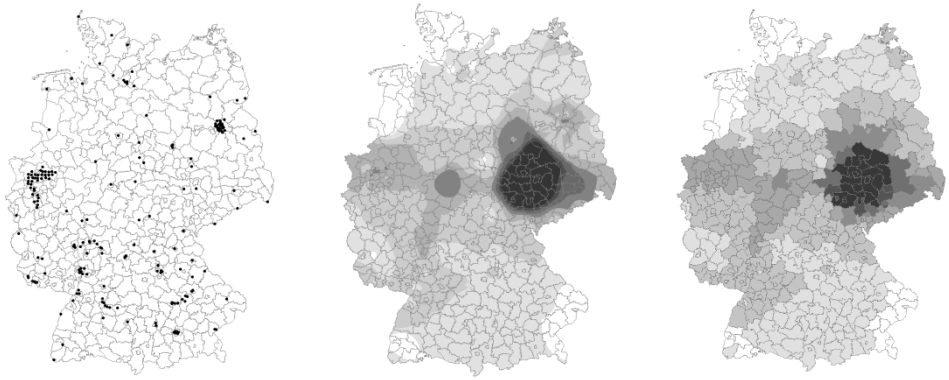
inverse cubed distance ($D_{ij}^{-3}$) as weights (method of inverse distance weighting). Specifically, grid values are estimated according to equation 5:

$$(5) \qquad grid\ value_i = \sum_{j=1}^{9} monitor\ reading_j \cdot D_{ij}^{-3} \Big/ \sum_{j=1}^{9} D_{ij}^{-3} .$$

The parameters have been suggested by the UBA, but interpolated values are similar for slightly different parameters. The interpolated mean $SO_2$ concentration for 1985 is shown in panel B of figure 1. In order to match the pollution data with the survey data, we aggregate the interpolated values on the level of German *Kreise* and *kreisfreie Städte* (roughly corresponding to U.S. counties); annual mean $SO_2$ concentrations are estimated using polygon data describing the boundaries of these administrative units.[23] The mean $SO_2$ concentration per county is depicted in panel C of figure 1 for the year 1985 and in panel A of figure 3 for the years 1985, 1990, 1995 and 2000.

*Figure 1*. Air quality monitors and mean annual $SO_2$ concentration, interpolated and aggregated at county level, 1985

A. Monitors B. Interpolated C. Aggregated



*Legend*: ☐ ≤ 20 μg/m³, ☐ 20 - 40 μg/m³, ☐ 40 - 60 μg/m³, ☐ 60 - 80 μg/m³, ☐ 80 - 100 μg/m³, ☐ 100 - 125 μg/m³, ☐ 125 - 150 μg/m³ and ☐ > 150 μg/m³.
*Sources*: UBA, own estimates.

The pattern and evolution of $SO_2$ pollution reveals two striking features. First, in the mid-1980s, pollution was highly concentrated at three hotspots. The three hotspots are the Ruhrge-

[23] In 1994, population per county was between 31,800 in Klingenthal and 2,170,000 in West Berlin with a median of 131,400. Following reunification, several counties in the former GDR were merged. Therefore, the number of counties fell from 543 in 1993 to 439 in 2001. The polygon data used for aggregation describe the boundaries of the 445 counties existing in 1996. Therefore, we assign the same $SO_2$ concentration to several counties in earlier years and calculate area-weighted averages for later years.

biet in the west, Nordhessen in the centre and the area around Leipzig in the east, by then all important industrial centers and coal mining areas. Second, air quality improved dramatically between 1985 and 1990 in the Federal Republic of Germany (FRG) and after 1990 in the former German Democratic Republic (GDR). In large part, these improvements reflect the effect of air quality regulations. As a result of an amendment to the *Grossfeuerungsanlagenverordnung* (large combustion plant ordinance) enacted in 1983, fossil fuel fired power plants had to be retrofitted with flue gas desulfurization, switch to low sulfur fuel or were subjected to early closure. Time limits were in the range between three and nine years from 1986 on and differed according to the capacity of a power plant and its actual emissions. With the *Einigungsvertrag* (unification treaty) signed in 1990, power plants in the former GDR were subjected to the same regulations. However, the pattern and evolution of $SO_2$ pollution also points at the potential simultaneity of local economic activity and pollution. Since 1980, the Ruhrgebiet has been undergoing structural change. New jobs in the service sector compensate only partially for job losses in the industrial sector. Similarly, the area around Leipzig is still recovering from the collapse of industrial production after reunification.

Failure to control for this simultaneity would bias the pollution coefficients in the life satisfaction and hedonic rent regression towards zero or may even lead to perverse results. To address this potential source of bias, we develop a novel instrument that exploits the facts that $SO_2$ is primarily emitted by large stationary sources and that regulations required retrofitting of power plants, coupled with information on the geography of power plants and wind directions.

We use the changes in $SO_2$ concentration caused by the large combustion plant ordinance and the consequent retrofitting of power plants as an instrument for $SO_2$ pollution. The changes in $SO_2$ concentration are estimated using a kind of difference-in-difference analysis. Thereby, desulfurization at power plants constitutes the treatment and counties are assigned to control and treatment groups according to prevailing wind directions at power plants. The improvement in air quality caused by flue gas desulfurization is estimated as the difference in the pre- and post-desulfurization difference in pollution concentrations between upwind and downwind counties or, alternatively, as the pre- and post-desulfurization difference in the difference between upwind and downwind concentrations. The identifying assumption in later stages of the analysis is that there exists no systematic difference in the effect of retrofitting of power plants on reported life satisfaction and rents between upwind and downwind counties *except* through

the effect on pollution. From the point of view of individual regions, the installation of scrubbers at large power plants (the single most important reason for the improvement in air quality) amounts to a natural experiment. Although the statutory provisions are the result of a political choice at the national level, they disproportionately benefit downwind regions compared to upwind regions.[24]

The actual analysis departs from this idealized difference-in-difference setting in two respects. First, as we consider simultaneously all power plants and all counties, the treatment is a weighted average of desulfurization at all plants with pre-desulfurization emissions of the plants and a function of the distance between particular plants and counties as weights. Second, only very few counties are completely untreated or completely treated and thus entirely in the control or treatment group. Depending on the frequency distribution of wind directions, they lie more or less often upwind or downwind of a power plant. In what follows, we explain more precisely the construction of the instrument. For details about data and data sources, we refer to the appendix to chapter 3 in the section 3.6.

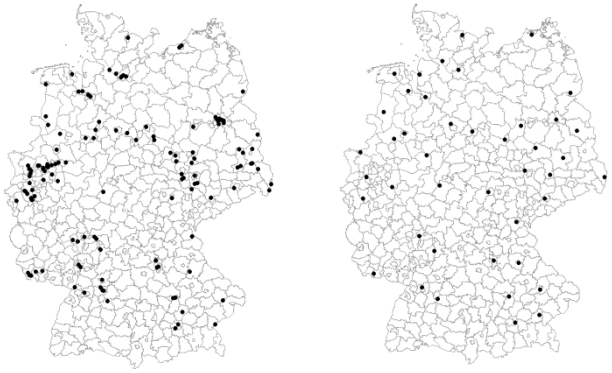
A key role in our analysis play estimates of annual $SO_2$ emissions (before desulfurization) for the largest power plants, information on when plants installed scrubbers, wind directions at the plants as well as direction and distance vectors between counties and plants. For 303 fossil fuel fired generating units, i.e. all units active between 1985 and 2003 with an electricity capacity of 100 MW and more, we have information on the launching year, the refit (desulfurization) year, the year the unit was shut down, capacity, fuel and fuel efficiency. The data are from the UBA, information published by the operating companies and the technical literature, a survey mailed to operating companies and statutory provisions. We georeference power plants using a route planer. The locations of the power plants are depicted in panel A of figure 2. With emission factors published in the literature and the plants' characteristics, annual $SO_2$ emissions can be estimated. Frequencies of wind directions in 12 30-degree sectors measured at 43 wind stations describe the wind situation at the power plants. From an originally larger sample of wind stations, we use for each plant the closest wind station. The stations are shown in panel B of figure 2. The predominant wind direction is west-southwest. At all power plants,

[24] It is worth noting that the costs of the regulation such as increased electricity prices and secondary benefits such as jobs created in the environmental industry are equally spatially distributed (or at least orthogonal to wind directions). Further, the statutory provisions were enacted before the period considered. Therefore, the actual installation of scrubbers does not reflect a shift in political power from upwind to downwind regions.

some wind directions clearly prevail, thus distinguishing counties into windward and leeward counties. In order to relate the data at the plant level with the pollution data at the county level, we calculate the Euclidean distance and direction between every power plant and every county.

*Figure 2*. Locations of fossil fuel fired power plants and wind stations

A. Power plants B. Wind stations



*Sources*: UBA, information published by operating companies, technical literature, route planner and Traup and Kruse (1996).

We can use these data to explain $SO_2$ concentrations at the county level and calculate fitted values and counterfactual pollution levels of a hypothetical situation without retrofitting of power plants. The difference between the counterfactual and the fitted values measures the improvement in air quality caused by the installation of scrubbers at power plants. The difference is our instrument for $SO_2$ pollution in later stages of the analysis.

The $SO_2$ concentration in county $c$ at time $t$, $P_{ct}$, can be explained by the product of a dummy variable indicating whether power plant $j$ is active at time $t$, $1(active)_{jt}$, estimated annual emissions at plant $j$ before desulfurization, $E_j$, the average separation efficiency of scrubber that is to be estimated, $\beta_2$, a dummy variable indicating whether plant $j$ has a scrubber installed at time $t$, $1(scrubber)_{jt}$, a distance decay function, $f(D_{cj})$, and the frequency the county $c$ lies downwind of plant $j$, $g(R_{cj})$, summed over all power plants as well as county and time specific fixed effects, $\chi_c$ and $\tau_t$, respectively. Equations 6a and 6b summarize the specification:

(6a) $$P_{ct} = \beta_0 + \beta_1 \sum_j 1(active)_{jt} \cdot E_j \cdot (1 - \beta_2 \cdot 1(scrubber)_{jt}) \cdot f(D_{cj}) \cdot g(R_{cj}) + \chi_c + \tau_t + \varepsilon_{ct},$$

or,

(6b) $$P_{ct} = \beta_0 + \beta_1 \sum_j 1(active)_{jt} \cdot E_j \cdot f(D_{cj}) \cdot g(R_{cj}) - \beta_1 \beta_2 \sum_j 1(active)_{jt} \cdot E_j \cdot 1(scrubber)_{jt} \cdot f(D_{cj}) \cdot g(R_{cj}) + \chi_c + \tau_t + \varepsilon_{ct}$$

In equation 6b, the second term on the right hand side denotes the sum of uncleaned $SO_2$ emissions, i.e. emissions before flue gas desulfurization, from all power plants weighted by a distance decay function and the frequency distribution of wind directions (hereafter 'weighted sum of uncleaned $SO_2$ emissions' for short), the third term denotes the sum of retained $SO_2$ emissions. We use two different functions to model the distance decay. In a first and simple variant, the emissions of all power plants within a distance of 450 km get a weight of one, all other emissions get zero weight; 450 km lies in the range of mean transport distances documented in the literature. In a second variant, the distance decay is modeled as an exponential curve with an implied characteristic distance decay distance of 480 km, $f(D_{cj}) = e^{-2.1E\text{-}6 \cdot Dcj}$, as suggested by field studies (Schwartz, S. E. 1989; Summers and Fricke 1989). Table 4 presents the results, column I the results for the first distance decay function, column II for the second.

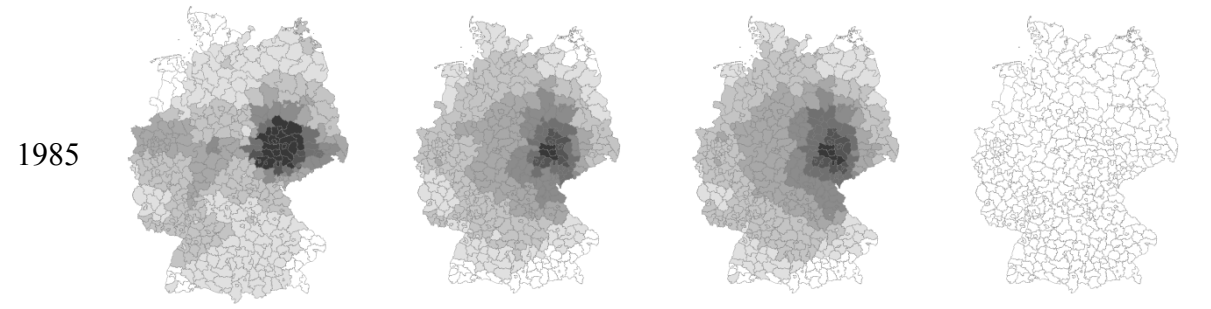
*Table 4.* Effect of fossil fuel fired power plants and flue gas desulfurization on $SO_2$ concentration

| *Dependent Variable* | I | | II | |
|---|---|---|---|---|
| $SO_2$ ($\mu g/m^3$) concentration | Coefficient | t-value | Coefficient | t-value |
| *Emissions from power plants* | | | | |
| Weighted sum of uncleaned $SO_2$ emissions | 3.7E-06** | 9.10 | 1.4E-05** | 17.64 |
| Weighted sum of retained $SO_2$ emissions | -4.2E-06** | -35.90 | -9.9E-06** | -36.46 |
| *County specific effects* | Yes | | Yes | |
| *Year specific effects* | Yes | | Yes | |
| *Constant* | Yes | | Yes | |
| Number of observations | | 8,455 | | 8,455 |
| Prob > F | | 0.000 | | 0.000 |
| $R^2$ | | 0.663 | | 0.672 |
| | Coefficient | St. Err. | Coefficient | St. Err. |
| Estimated separation efficiency | -1.156** | 0.128 | -0.686** | 0.042 |

*Notes*: (1) OLS estimates. (2) ** is significant at the 99% level. (3) Standard errors for the separation efficiency are estimates using the delta method.

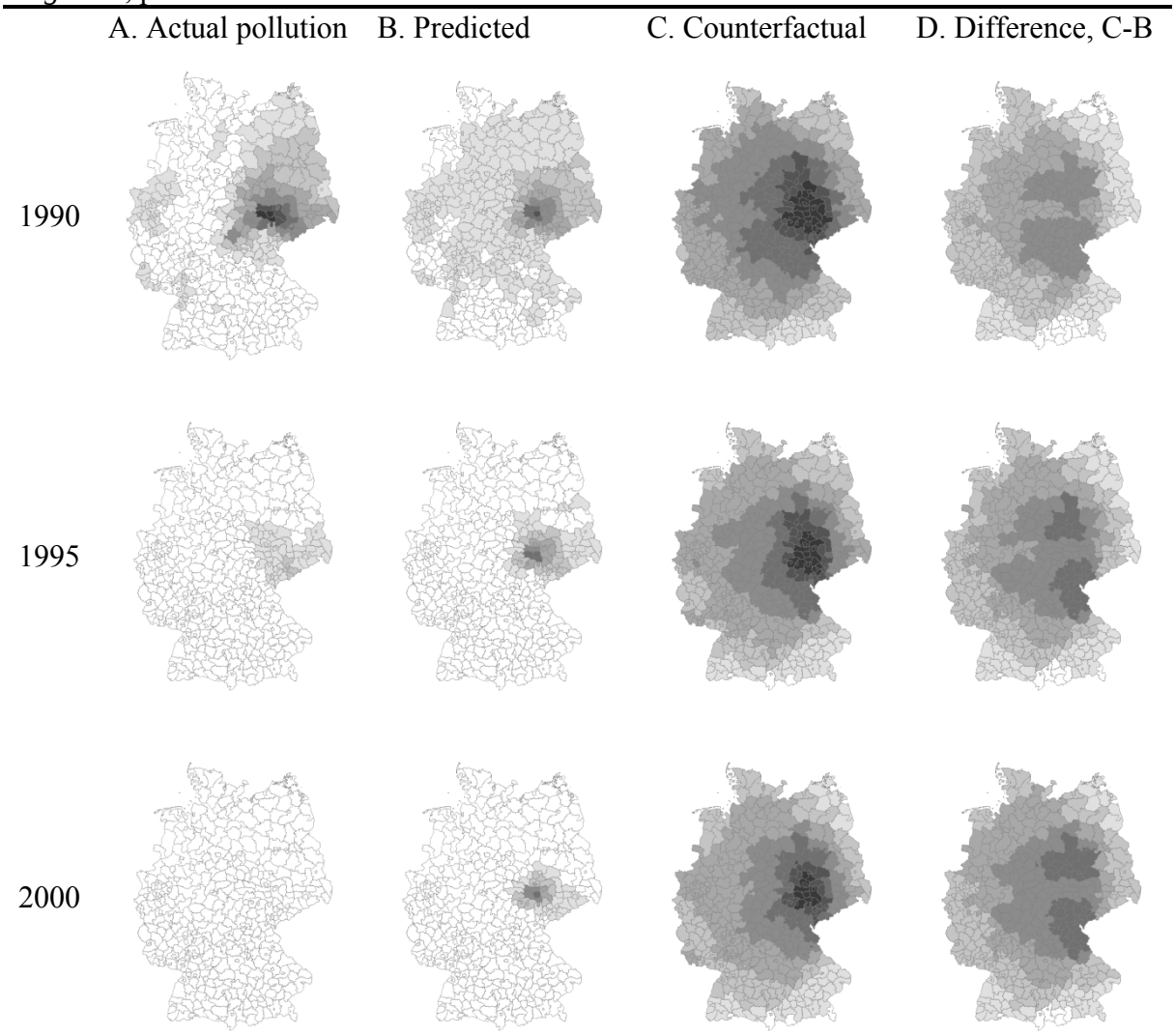
As expected, the sum of uncleaned $SO_2$ emissions at power plants increases, and the sum of retained emission decreases, measured air pollution. Using the coefficient for the uncleaned and the retained emissions, we estimate separation efficiencies of 116% and 69%, respectively; standard errors are estimated using the delta method. In a first plausibility test of the results, actual separation efficiencies serve as a benchmark. Statutory provisions in Germany require a separation efficiency of 60% at the smallest units and more efficient scrubbers at larger units; separation efficiency at the largest power plants lies typically in the range of 90% to 99%. While the separation efficiency estimated with the first model is not statistically significantly different from actual values, the separation efficiency estimated with the second model is marginally below actual values. Second, a visual comparison of the actual pollution levels ($P_{ct}$) and the fitted values ($\hat{P}_{ct}$) based on the first model for the four years shown in panels A and B of figure 3 as well as the $R^2$ reveal a satisfactory goodness-of-fit. We are now in a position to estimate counterfactual pollution levels for a hypothetical situation without installation of scrubber at power plants ($\tilde{P}_{ct}$) and the difference between the counterfactual and predicted pollution levels ($\tilde{P}_{ct} - \hat{P}_{ct}$). This difference is an estimate of the causal effect of flue gas desulfurization and is our instrument for $SO_2$ pollution. The counterfactual pollution levels and the instrument based on the first model are shown in panel C and D of figure 3.

*Figure 3*. Actual, predicted and counterfactual $SO_2$ concentration and difference between predicted and counterfactual concentration; 1985, 1990, 1995 and 2000




*To be continued.*

*Figure 3*, part 2




*Legend*: ☐ ≤ 20 μg/m$^3$, ☐ 20 - 40 μg/m$^3$, ☐ 40 - 60 μg/m$^3$, ☐ 60 - 80 μg/m$^3$, ☐ 80 - 100 μg/m$^3$, ☐ 100 - 125 μg/m$^3$, ■ 125 - 150 μg/m$^3$ and ■ > 150 μg/m$^3$.
*Sources*: UBA, own estimates.

## 3.3 Effects on life satisfaction

### 3.3.1 Data and empirical strategy

In order to examine the impact of air pollution on life satisfaction and housing rents, we use the GSOEP containing information on both, individual life satisfaction and rents. The GSOEP is a nationally representative panel that closely follows a large number of households and individuals since 1984. Following the fall of the Berlin wall, the panel was extended to include residents of the former GDR. The baseline life satisfaction regressions are based on a panel for

the period 1985-2003 consisting of 33,864 individuals who remain in the panel on average for 6.7 years.

As already mentioned in section 2.2.2, the GSOEP elicits individual life satisfaction with the following question: "How satisfied are you at present with your life, all things considered?" The responses run from 0 (completely dissatisfied) to 10 (completely satisfied). The mean reported life satisfaction in our sample is 7.07 (std. dev. 1.75).

Apart from the pollution data, another important explanatory variable is post-government household income as a measure of disposable income. Its coefficient is later used for monetization. The variable is the sum of total household income from labor earnings (including bonuses etc.), asset flows, private retirement income, public and private transfers and social security pensions minus total household taxes. Except estimates of tax burden, which are based on tax calculation routines, all other components are actually received incomes as declared in the survey of the subsequent year. Thus, income information for households exiting the panel in the following year is not available. Further, the information is missing for East Germany in the year 1990.

Estimating the effect of income on life satisfaction is afflicted with serious problems of endogeneity and omitted variables. Happy people earn more and time-varying factors may lead to both greater satisfaction and higher income (e.g. Clark, Frijters and Shields 2007; Gardner and Oswald 2007). A related problem is that costs of income generation such as working hours, stress, health risks etc. are inherently difficult to control for. Omission of such factors induces downward biased estimates. To address these problems, we instrument income with a predictor of household income and with job tenure of the main income earner, or if the respondent is the main income earner, job tenure of the secondary income earner. Our predictor of household income is similar in spirit to the one used by Luttmer (2005). We predict labor earnings for around 5,000 *industry · occupation* cells by regressing log labor earnings on a full set of industry and occupation dummies, for each year, and for West and East Germany, separately. The exponential of the fitted values of these regressions are the predicted earnings for individuals in each *industry · occupation* in a particular region and year. Summing over all household members, we get a prediction of household income. Therefore, increases in pre-

dicted household income reflect industry and/or occupation wide factors but not exceptional personal efforts by one of the household members.

Based on theoretical considerations and convention, we include household income in its natural logarithm (see Layard, Mayaraz and Nickell 2006 for a study on the functional form between income and life satisfaction) and control for the square root of household size in order to capture the effect of household size on equivalence income.

Following the previous literature, we include the most commonly used observable *time-varying* predictors of life satisfaction (Frijters, Haisken-DeNew and Shields 2004; Stutzer and Frey 2004; Ferrer-i-Carbonell 2005). These are age (or rather age squared), disability status, marital and partnership status, labor force status, occupational position, type of employment contract and city or district size. We add own job tenure and average weekly working hours to this list because our instruments for household income might only be valid conditional on these two variables. For example, in bargaining collective work agreements, unions may accept industry wide income reductions in return for a shorter workweek, thereby reducing both income and effort cost. Dummies for individuals participating in the survey for the first and second time, respectively, serve as a proxy for interviewing experience and panel learning effects (D'Ambrosio and Frick 2004). In order to control for the secular upward trend in life satisfaction in post-reunification years in East Germany documented by Frijters, Haisken-DeNew and Shields (2004), we include state specific time trends along with a full set of state and year fixed effects.[25] Finally, a fixed effect model is appropriate as fixed personality traits are important predictors of life satisfaction (Ferrer-i-Carbonell and Frijters 2004). The equation to be estimated in the second stage is thus

$$(7) \qquad LS_{icst} = \beta_0 + \beta_1 P_{cst} + \beta_2 \ln(m_{icst}) + \beta_3 Z_{icst} + \beta_4 trend_s + \sigma_s + \tau_t + \iota_i + \varepsilon_{icst},$$

where $LS_{icst}$ is the life satisfaction of respondent $i$ living in county $c$ in state $s$ at time $t$, $P_{cst}$ pollution at county level, $m_{icst}$ respondent's household income, $Z_{icst}$ a vector of personal char-

[25] Due to German data protection laws, we are not allowed to have the regional data on our local computer but are obliged to use the remote access to the GSOEP, SOEPremote. Because of memory restrictions at the DIW, the host of SOEPremote, we cannot estimate models with county specific effects. However, we observe only around 10% of respondents in more than one county. If we restrict our sample to the individuals who do not move across county boundaries, the results are very similar. For all individuals who remain within the county boundaries, county specific effects are captured by the individual specific fixed effects. Therefore, the results are not driven by unobserved county characteristics. The results are available upon request from the authors.

acteristics, $trend_s$ state specific time trends, $\sigma_s$, $\tau_t$ and $\iota_i$ state, year and individual fixed effects, respectively, and $\varepsilon_{icst}$ an error term. Generally, we estimate equation 7 by instrumental variables, using the estimated effect of flue gas desulfurization as an instrument for $SO_2$ pollution and job tenure of the main or secondary income earner and the predictor of household income as instruments for income. Robust standard errors are adjusted for clustering on county and year level. Equation 7 is estimated by ordinary least squares. As discussed in section 2.2.3 and as can be seen in chapters 4 and 5, assuming ordinality or cardinality of life satisfaction scores makes little difference.

### 3.3.2 Basic results

Table 5 reports the basic life satisfaction regressions in full with the results for all control variables. The effects of the control variables contain no surprises and correspond to results documented in the literature (Frijters, Haisken-DeNew and Shields 2004; Stutzer and Frey 2004; Ferrer-i-Carbonell 2005). Of all personal characteristics, being unemployed exerts the largest (negative) effect on life satisfaction. This is a well-documented finding in the previous literature (see e.g. Clark and Oswald 1994; Winkelmann and Winkelmann 1998). The control variables are included in all regressions but, for the sake of brevity, we do not report the estimates in the subsequent tables.

The variables of interest are $SO_2$ concentration and household income. Both have the expected sign and are statistically significant. We will discuss the size of the effect extensively in section 3.5 in which we monetize the effect. The raw coefficients are difficult to interpret and cannot be readily compared to the earlier estimates of pollution on life satisfaction reported in section 2.4.1, except with respect to sign and significance. Welsch (2002) finds essentially no effect of $SO_2$ concentration on happiness in his cross-section of 54 countries, both in terms of size and significance. Di Tella and MacCulloch (2005a) find a negative and statistically significant effect of $SO_2$ emissions in their repeated cross-section of 12 countries and 23 years, but there is no general method to convert emissions into pollution levels. Finally, Welsch (2006) only considers other pollutants.

*Table 5*. Basic results: Effect of $SO_2$ pollution on life satisfaction, Germany 1985-2003

**A. Second stage regression**

| *Dependent Variable* | I | | II | | III | | IV | | V | | VI | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Life satisfaction | Coef. | z-value | Coef. | z-value | Coef. | z-value | Coef. | z-value | Coef. | z-value | Coef. | z-value |
| *Pollution* | | | | | | | | | | | | |
| $SO_2$ ($\mu g/m^3$) | -0.005 ** | -6.95 | -0.010 * | -2.38 | -0.006 (*) | -1.80 | -0.004 ** | -6.45 | -0.010 ** | -2.56 | -0.006 (*) | -1.91 |
| *HH income* | | | | | | | | | | | | |
| ln(post govt. income) | 0.140 ** | 14.94 | 0.138 ** | 14.62 | 0.139 ** | 14.81 | 0.484 ** | 8.94 | 0.482 ** | 8.90 | 0.484 ** | 8.93 |
| HH size$^{1/2}$ | -0.167 ** | -7.82 | -0.168 ** | -7.85 | -0.167 ** | -7.82 | -0.379 ** | -9.69 | -0.380 ** | -9.69 | -0.379 ** | -9.68 |
| *Personal characteristics* | | | | | | | | | | | | |
| Age$^2$ | -9E-5 ** | -2.67 | -9E-5 ** | -2.77 | -9E-5 ** | -2.70 | -8E-5 * | -2.55 | -9E-5 ** | -2.68 | -8E-5 ** | -2.59 |
| Not disabled | Reference group | | Reference group | | Reference group | | Reference group | | Reference group | | Reference group | |
| Disabled | -0.225 ** | -11.03 | -0.227 ** | -11.13 | -0.226 ** | -11.08 | -0.228 ** | -11.14 | -0.231 ** | -11.25 | -0.229 ** | -11.20 |
| Single, no partner | Reference group | | Reference group | | Reference group | | Reference group | | Reference group | | Reference group | |
| Single, with partner | 0.163 ** | 7.19 | 0.162 ** | 7.14 | 0.163 ** | 7.19 | 0.168 ** | 7.37 | 0.166 ** | 7.31 | 0.167 ** | 7.36 |
| Married | 0.245 ** | 9.99 | 0.246 ** | 10.01 | 0.245 ** | 9.98 | 0.236 ** | 9.59 | 0.237 ** | 9.62 | 0.236 ** | 9.59 |
| Separated, no partner | -0.319 ** | -6.55 | -0.319 ** | -6.54 | -0.319 ** | -6.55 | -0.282 ** | -5.72 | -0.282 ** | -5.72 | -0.282 ** | -5.72 |
| Separated, with partner | 0.098 | 1.24 | 0.097 | 1.23 | 0.098 | 1.24 | 0.103 | 1.30 | 0.101 | 1.29 | 0.102 | 1.30 |
| Divorced, no partner | -0.032 | -0.81 | -0.032 | -0.82 | -0.032 | -0.81 | -0.006 | -0.16 | -0.007 | -0.17 | -0.006 | -0.16 |
| Divorced, with partner | 0.318 ** | 7.47 | 0.318 ** | 7.48 | 0.318 ** | 7.47 | 0.311 ** | 7.31 | 0.311 ** | 7.33 | 0.311 ** | 7.31 |
| Widowed, no partner | -0.230 ** | -4.95 | -0.228 ** | -4.90 | -0.230 ** | -4.93 | 0.252 ** | 5.40 | -0.250 ** | -5.34 | -0.251 ** | -5.37 |
| Widowed, with partner | 0.338 ** | 3.78 | 0.338 ** | 3.77 | 0.338 ** | 3.78 | -0.283 ** | -3.17 | 0.283 ** | 3.17 | 0.283 ** | 3.17 |
| Spouse in home country | -0.110 | -1.23 | -0.112 | -1.25 | -0.110 | -1.24 | -0.098 | -1.07 | -0.100 | -1.10 | -0.098 | -1.08 |
| No children in HH | Reference group | | Reference group | | Reference group | | Reference group | | Reference group | | Reference group | |
| Children in HH | 0.053 ** | 3.94 | 0.053 ** | 3.96 | 0.053 ** | 3.94 | 0.094 ** | 6.34 | 0.095 ** | 6.35 | 0.094 ** | 6.34 |
| German citizen | Reference group | | Reference group | | Reference group | | Reference group | | Reference group | | Reference group | |
| EU citizen | -0.184 * | -2.03 | -0.182 * | -2.02 | -0.183 * | -2.03 | -0.185 * | -2.03 | -0.182 * | -2.01 | -0.184 * | -2.03 |
| Non EU foreigner | -0.049 | -0.94 | -0.045 | -0.87 | -0.048 | -0.92 | -0.052 | -0.99 | -0.048 | -0.91 | -0.050 | -0.97 |

*To be continued.*

*Table 5*, part 2

| | I | | II | | III | | IV | | V | | VI | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Coef. | z-value | Coef. | z-value | Coef. | z-value | Coef. | z-value | Coef. | z-value | Coef. | z-value |
| Not working | Reference group | | Reference group | | Reference group | | Reference group | | Reference group | | Reference group | |
| Retired | 0.194 ** | 8.70 | 0.193 ** | 8.62 | 0.194 ** | 8.68 | 0.193 ** | 8.60 | 0.191 ** | 8.52 | 0.192 ** | 8.58 |
| In education | 0.257 ** | 9.32 | 0.254 ** | 9.21 | 0.256 ** | 9.31 | 0.249 ** | 8.86 | 0.246 ** | 8.74 | 0.248 ** | 8.83 |
| Maternity leave | 0.164 ** | 5.58 | 0.165 ** | 5.63 | 0.164 ** | 5.59 | 0.158 ** | 5.36 | 0.160 ** | 5.42 | 0.159 ** | 5.38 |
| Military, community service | -0.027 | -0.56 | -0.028 | -0.60 | -0.027 | -0.57 | -0.026 | -0.54 | -0.028 | -0.59 | -0.027 | -0.56 |
| Unemployed | -0.443 ** | -19.70 | -0.443 ** | -16.69 | -0.443 ** | -19.70 | -0.454 ** | -20.02 | -0.454 ** | -20.01 | -0.454 ** | -20.02 |
| Sometimes working | 0.046 | 1.30 | 0.048 | 1.37 | 0.046 | 1.32 | 0.031 | 0.87 | 0.034 | 0.95 | 0.032 | 0.89 |
| Full-time employment | 0.179 ** | 7.25 | 0.182 ** | 7.32 | 0.180 ** | 7.24 | 0.119 ** | 4.54 | 0.122 ** | 4.65 | 0.120 ** | 4.56 |
| Part-time employment | 0.037 (*) | 1.67 | 0.039 (*) | 1.74 | 0.038 (*) | 1.68 | 0.001 | 0.03 | 0.003 | 0.12 | 0.001 | 0.06 |
| Vocational training | 0.134 * | 2.37 | 0.135 * | 2.39 | 0.134 * | 2.37 | 0.070 | 1.22 | 0.071 | 1.25 | 0.070 | 1.23 |
| Other employment | 0.012 | 0.34 | 0.013 | 0.36 | 0.012 | 0.34 | -0.003 | -0.09 | -0.002 | -0.06 | -0.003 | -0.08 |
| Blue collar worker | Reference group | | Reference group | | Reference group | | Reference group | | Reference group | | Reference group | |
| Trainee | 0.144 ** | 2.81 | 0.142 ** | 2.77 | 0.144 ** | 2.80 | 0.176 ** | 3.41 | 0.174 ** | 3.37 | 0.175 ** | 3.40 |
| Public service employee | -0.043 | -1.22 | -0.040 | -1.16 | -0.042 | -1.21 | -0.035 | -1.00 | -0.032 | -0.92 | -0.034 | -0.97 |
| White collar worker | 0.015 | 1.06 | 0.015 | 1.04 | 0.015 | 1.06 | 0.012 | 0.82 | 0.011 | 0.80 | 0.012 | 0.81 |
| Managerial position | 0.112 ** | 5.29 | 0.114 ** | 5.37 | 0.112 ** | 5.31 | 0.086 ** | 3.97 | 0.088 ** | 4.08 | 0.087 ** | 4.00 |
| Temporary employment | -0.063 ** | -3.38 | -0.063 ** | -3.39 | -0.063 ** | -3.38 | -0.051 ** | -2.74 | -0.052 ** | -2.75 | -0.051 ** | -2.74 |
| Permanent employment | 0.056 ** | 4.95 | 0.057 ** | 5.03 | 0.057 ** | 4.96 | 0.056 ** | 4.87 | 0.057 ** | 4.96 | 0.056 ** | 4.89 |
| Job tenure | -0.004 ** | -5.04 | -0.004 ** | -5.17 | -0.004 ** | -5.04 | -0.004 ** | -5.75 | -0.005 ** | -5.92 | -0.004 ** | -5.78 |
| Actual working hours | 1E-4 ** | 2.73 | 1E-4 ** | 2.63 | 1E-4 ** | 2.70 | 6E-5 | 1.61 | 6E-5 | 1.49 | 6E-5 | 1.57 |
| First interview | 0.203 ** | 12.62 | 0.212 ** | 12.01 | 0.205 ** | 11.94 | 0.190 ** | 11.67 | 0.201 ** | 11.30 | 0.194 ** | 11.16 |
| Second interview | 0.061 ** | 4.25 | 0.077 ** | 3.99 | 0.065 ** | 3.66 | 0.058 ** | 4.05 | 0.077 ** | 4.01 | 0.064 ** | 3.63 |
| Third and later interviews | Reference group | | Reference group | | Reference group | | Reference group | | Reference group | | Reference group | |

*To be continued.*

*Table 5*, part 3

| | I | | II | | III | | IV | | V | | VI | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Coef. | z-value | Coef. | z-value | Coef. | z-value | Coef. | z-value | Coef. | z-value | Coef. | z-value |
| *City, district size* | | | | | | | | | | | | |
| Less than 2,000 | Reference group | | Reference group | | Reference group | | Reference group | | Reference group | | Reference group | |
| Less than 20,000 | -0.006 | -0.21 | -0.006 | -0.21 | -0.006 | -0.21 | -0.008 | -0.31 | -0.008 | -0.31 | -0.008 | -0.31 |
| Less than 100,000 | 0.033 | 1.13 | 0.035 | 1.20 | 0.034 | 1.15 | 0.029 | 0.99 | 0.032 | 1.07 | 0.030 | 1.01 |
| Less than 500,000 | -0.012 | -0.38 | -0.009 | -0.28 | -0.011 | -0.36 | -0.004 | -0.13 | -4E-4 | -0.01 | -0.003 | -0.09 |
| Over 500,000 | -0.051 | -1.40 | -0.048 | -1.31 | -0.050 | -1.37 | -0.047 | -1.27 | -0.044 | -1.18 | -0.046 | -1.24 |
| *State specific effects* | Yes | | Yes | | Yes | | Yes | | Yes | | Yes | |
| *State specific time trends* | Yes | | Yes | | Yes | | Yes | | Yes | | Yes | |
| *Year specific effects* | Yes | | Yes | | Yes | | Yes | | Yes | | Yes | |
| *Individual specific effects* | Yes | | Yes | | Yes | | Yes | | Yes | | Yes | |
| Prob > F | | 0.000 | | 0.000 | | 0.000 | | 0.000 | | 0.000 | | 0.000 |
| $R^2$ within | | 0.037 | | 0.036 | | 0.037 | | 0.028 | | 0.028 | | 0.029 |
| $R^2$ between | | 0.066 | | 0.066 | | 0.066 | | 0.086 | | 0.086 | | 0.086 |
| $R^2$ overall | | 0.057 | | 0.056 | | 0.057 | | 0.063 | | 0.062 | | 0.063 |
| **B. First stage regressions** | | | | | | | | | | | | |
| *Dependent Variable* | | | | | | | | | | | | |
| $SO_2$ ($\mu g/m^3$) | | | | | | | | | | | | |
| *Excluded instruments* | | | | | | | | | | | | |
| Predicted $\Delta SO_2$ | | | -0.200 ** | -13.66 | -0.217 ** | -19.32 | | | -0.200 ** | -13.64 | -0.217 ** | -19.31 |
| ln(predicted HH income) | | | | | | | | | 0.012 | 1.08 | 0.012 | 1.09 |
| Tenure income earner | | | | | | | | | -0.012 * | -2.48 | -0.011 * | -2.39 |
| *Included instruments* | | | Yes | | Yes | | Yes | | Yes | | Yes | |

*To be continued.*

*Table 5*, part 4

| | I | | II | | III | | IV | | V | | VI | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Coef. | z-value | Coef. | z-value | Coef. | z-value | Coef. | z-value | Coef. | z-value | Coef. | z-value |
| *Dependent Variable* | | | | | | | | | | | | |
| ln(post govt. income) | | | | | | | | | | | | |
| *Excluded instruments* | | | | | | | | | | | | |
| Predicted $\Delta SO_2$ | | | | | | | | | -3E-4 | -1.12 | -1E-4 | -0.67 |
| ln(predicted HH income) | | | | | | | 0.026 ** | 37.09 | 0.026 ** | 37.06 | 0.026 ** | 37.05 |
| Tenure income earner | | | | | | | 0.005 ** | 27.66 | 0.005 ** | 27.75 | 0.005 ** | 27.75 |
| *Included instruments* | | | | | | | Yes | | Yes | | Yes | |
| Number of observations | 227,789 | | 227,789 | | 227,789 | | 227,789 | | 227,789 | | 227,789 | |
| Number of individuals | 33,864 | | 33,864 | | 33,864 | | 33,864 | | 33,864 | | 33,864 | |
| Avg. no. of obs. per individual | 6.7 | | 6.7 | | 6.7 | | 6.7 | | 6.7 | | 6.7 | |
| Number of clusters | 7,413 | | 7,413 | | 7,413 | | 7,413 | | 7,413 | | 7,413 | |
| Shea's partial $R^2$ for $SO_2$ | | | 0.025 | | 0.043 | | | | 0.025 | | 0.043 | |
| Bound et al. partial $R^2$ | | | 0.025 | | 0.043 | | | | 0.025 | | 0.043 | |
| F-test exc. instruments (p-value) | | | 0.000 | | 0.000 | | | | 0.000 | | 0.000 | |
| Shea's partial $R^2$ for log income | | | | | | | 0.028 | | 0.028 | | 0.028 | |
| Bound et al. partial $R^2$ | | | | | | | 0.028 | | 0.028 | | 0.028 | |
| F-test exc. instruments (p-value) | | | | | | | 0.000 | | 0.000 | | 0.000 | |
| Anderson LR statistic (p-value) | | | 0.000 | | 0.000 | | 0.000 | | 0.000 | | 0.000 | |
| Hansen's J statistic (p-value) | | | - | | - | | 0.254 | | 0.311 | | 0.271 | |

*Notes*: (1) OLS and IV estimates with individual fixed effects; $SO_2$ concentration is instrumented with the effect of flue gas desulfurization at power plants estimated with a distance decay modeled as an indicator function in specifications II and V and modeled with an exponential function in specifications III and VI; household income is instrumented with the sum of predicted incomes of the household members and job tenure of household of the primary/secondary wage earner in specifications IV, V and VI. (2) Standard errors are adjusted for clustering on county and year level. (3) ** is significant at the 99% level, * at the 95% level, and (*) at the 90% level.

The conventional estimates of $SO_2$ effects on life satisfaction (columns I and IV of table 5), i.e. the estimates not based on pollution instruments, are smaller in absolute terms compared to the estimates in which pollution is instrumented. If we use estimates of the causal effect of flue gas desulfurization based on an indicator distance decay function as an instrument (columns II and V), the effect of $SO_2$ on life satisfaction more than doubles; if we use estimates based on the exponential distance decay function as an instrument, the effect increases by approximately one third. The finding that the instrumental variables estimates are larger in absolute terms than the conventional estimate suggests that improvements in air quality are accompanied by negative developments. While the conventional estimate captures only the net effect between changes in pollution and the countervailing factors, the instrumental variable estimates capture the whole effect of changes in pollution. However, given the (generically) large standard errors of instrumental variable estimates, the difference between the instrumental variable estimates and the conventional estimate is not significant in a statistical sense. The difference becomes more pronounced for the estimates in which income is instrumented (columns IV to VI) because, in absolute terms, the conventional estimate of the effect of $SO_2$ slightly decreases and the estimates based on instrumental variables slightly increase (all changes are around 7%). These changes are difficult to interpret in terms of omitted variable biases and none of the changes is statistically significant.

Regarding the effect of log household income on life satisfaction, the conventional estimates (columns I to III) are slightly above the results reported by Ferrer-i-Carbonell and Frijters (2004) and, as far as different econometric models allow for a comparison, below the results reported in Ferrer-i-Carbonell (2005). The effect of instrumenting household income (columns IV to VI) suggests that the OLS estimates are indeed biased. The estimated effect of log household income on life satisfaction more than triples, a change of similar magnitude as the one reported by Luttmer (2005). The coefficients for income are stable across specifications.

Turning to the first stage regressions, we see that the instruments have the expected effect on the endogenous variables for which they are intended: the estimated effect of flue gas desulfurization negatively affects $SO_2$ concentration. Predicted household income and job tenure of the main or secondary income earner both have a positive impact on household income. Our pollution instruments have no effect on income (conditional on the other variables), which

suggests that the instrument is indeed orthogonal to local economic activity. For unknown reasons, job tenure is weakly negatively associated with $SO_2$ concentration.

It is important to sound a note of caution regarding the interpretation of the statistical significance in the first stage regressions. Two instruments, the estimated effect of flue gas desulfurization and predicted household income, are estimated regressors in the first stage regressions and, thus, standard errors are underestimated and t-statistics inflated. However, under general conditions, the parameters in the first stage regressions are consistently estimated (Murphy and Topel 1985). Therefore, the second stage regressions are not afflicted by the problem of estimated regressors.

In all cases, the statistical tests suggest that the instruments are relevant. Shea's (1997) partial $R^2$s are nearly identical to standard $R^2$s (Bound, Jaeger and Baker 1995), the Anderson canonical correlations likelihood-ratio tests reject the null of underidentification and F-tests indicate joint significance of the excluded instruments. Further, none of the Hansen's (1982) J-statistics rejects the null that the instruments are satisfying the orthogonality condition.

### 3.3.3 Robustness tests

Despite the efforts to instrument pollution, one might worry that levels of $SO_2$ concentration reflect local economic activity or air quality more generally. In a second set of regressions, we therefore include annual unemployment rates at county level and annual mean concentration of TSP as additional controls. Table 6 presents the results; the models presented in particular columns are identical to the models in the corresponding column of table 5, except for the two additional control variables.

Overall, the results are robust to the inclusion of local unemployment rate and TSP concentration. The coefficient of $SO_2$ instrumented with the effect of flue gas desulfurization estimated based on an indicator distance decay function slightly increases. In all models, standard errors of the coefficients of $SO_2$ increase, pushing the coefficient of $SO_2$ instrumented with estimates based on the exponential distance decay function presented in column III below conventional significance levels. The conventional pollution estimates are at least as robust as the instrumental variable estimates. The robustness of the conventional estimates contrasts somewhat

*Table 6*. Robustness check: Effect of $SO_2$ pollution on life satisfaction controlling for TSP and unemployment rate

| **A. Second stage regression** | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Dependent Variable* | I | | II | | III | | IV | | V | | VI | |
| Life satisfaction | Coef. | z-value | Coef. | z-value | Coef. | z-value | Coef. | z-value | Coef. | z-value | Coef. | z-value |
| *Pollution* | | | | | | | | | | | | |
| $SO_2$ ($\mu g/m^3$) | -0.005 ** | -6.87 | -0.011 * | -2.22 | -0.006 | -1.54 | -0.004 ** | -6.35 | -0.012 * | -2.39 | -0.006 (*) | -1.65 |
| TSP ($\mu g/m^3$) | -0.001 (*) | -1.67 | 1E-5 | 0.01 | -0.001 | -0.97 | -0.001 (*) | -1.68 | 2E-4 | 0.21 | -0.001 | -0.83 |
| *Unemployment rate* | -0.012 ** | -3.49 | -0.016 ** | -3.52 | -0.013 ** | -3.18 | -0.011 ** | -3.11 | -0.015 ** | -3.35 | -0.012 ** | -2.94 |
| *HH income* | | | | | | | | | | | | |
| ln(post govt. income) | 0.139 ** | 14.90 | 0.137 ** | 14.47 | 0.139 ** | 14.75 | 0.482 ** | 8.90 | 0.481 ** | 8.87 | 0.482 ** | 8.90 |
| *Personal characteristics* | Yes | | Yes | | Yes | | Yes | | Yes | | Yes | |
| *City, district size* | Yes | | Yes | | Yes | | Yes | | Yes | | Yes | |
| *State specific effects* | Yes | | Yes | | Yes | | Yes | | Yes | | Yes | |
| *State specific time trends* | Yes | | Yes | | Yes | | Yes | | Yes | | Yes | |
| *Year specific effects* | Yes | | Yes | | Yes | | Yes | | Yes | | Yes | |
| *Individual specific effects* | Yes | | Yes | | Yes | | Yes | | Yes | | Yes | |
| Prob > F | | 0.000 | | 0.000 | | 0.000 | | 0.000 | | 0.000 | | 0.000 |
| $R^2$ within | | 0.037 | | 0.036 | | 0.037 | | 0.029 | | 0.027 | | 0.029 |
| $R^2$ between | | 0.066 | | 0.066 | | 0.066 | | 0.086 | | 0.086 | | 0.086 |
| $R^2$ overall | | 0.057 | | 0.055 | | 0.057 | | 0.063 | | 0.062 | | 0.063 |
| **B. First stage regressions** | | | | | | | | | | | | |
| *Dependent Variable* | | | | | | | | | | | | |
| $SO_2$ ($\mu g/m^3$) | | | | | | | | | | | | |
| *Excluded instruments* | | | | | | | | | | | | |
| Predicted $\Delta SO_2$ | | | -0.169 ** | -11.94 | -0.191 ** | -17.22 | | | -0.169 ** | 11.92 | 0.191 ** | 17.21 |
| ln(predicted HH income) | | | | | | | | | 0.013 | 1.19 | 0.013 | 1.15 |
| Tenure income earner | | | | | | | | | -0.010 * | -2.21 | -0.010 * | -2.13 |
| *TSP and unemployment rate* | | | | | | | | | | | | |
| TSP ($\mu g/m^3$) | | | 0.129 ** | 10.52 | 0.120 ** | 9.66 | | | 0.129 ** | 10.53 | 0.120 ** | 9.67 |
| Unemployment rate | | | -0.489 ** | -5.32 | -0.487 ** | -5.34 | | | -0.487 ** | -5.30 | -0.485 ** | -5.33 |

*To be continued.*

*Table 6*, part 2

| | I | | II | | III | | IV | | V | | VI | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Coef. | z-value | Coef. | z-value | Coef. | z-value | Coef. | z-value | Coef. | z-value | Coef. | z-value |
| *Included instruments* | | | Yes | | Yes | | | | Yes | | Yes | |
| *Dependent Variable* | | | | | | | | | | | | |
| ln(post govt. income) | | | | | | | | | | | | |
| *Excluded instruments* | | | | | | | | | | | | |
| Predicted $\Delta SO_2$ | | | | | | | | | 2E-4 | 0.98 | -1E-4 | -0.59 |
| ln(predicted HH income) | | | | | | | 0.026 ** | 37.06 | 0.026 ** | 37.02 | 0.026 ** | 37.01 |
| Tenure income earner | | | | | | | 0.005 ** | 27.71 | 0.005 ** | 27.79 | 0.005 ** | 27.79 |
| *TSP and unemployment rate* | | | | | | | | | | | | |
| TSP ($\mu g/m^3$) | | | | | | | 1E-4 | 0.79 | -6E-5 | -0.48 | -6E-5 | -0.42 |
| Unemployment rate | | | | | | | -0.004 ** | -3.72 | -0.003 ** | -3.04 | -0.003 ** | -3.10 |
| *Included instruments* | | | | | | | Yes | | Yes | | Yes | |
| Number of observations | 227,789 | | 227,789 | | 227,789 | | 227,789 | | 227,789 | | 227,789 | |
| Number of individuals | 33,864 | | 33,864 | | 33,864 | | 33,864 | | 33,864 | | 33,864 | |
| Avg. no. of obs. per individual | 6.7 | | 6.7 | | 6.7 | | 6.7 | | 6.7 | | 6.7 | |
| Number of clusters | 7,413 | | 7,413 | | 7,413 | | 7,413 | | 7,413 | | 7,413 | |
| Shea's partial $R^2$ for $SO_2$ | | | 0.018 | | 0.034 | | | | 0.018 | | 0.034 | |
| Bound et al. partial $R^2$ | | | 0.018 | | 0.034 | | | | 0.018 | | 0.034 | |
| F-test exc. instruments (p-value) | | | 0.000 | | 0.000 | | | | 0.000 | | 0.000 | |
| Shea's partial $R^2$ for log income | | | | | | | 0.027 | | 0.027 | | 0.027 | |
| Bound et al. partial $R^2$ | | | | | | | 0.027 | | 0.027 | | 0.027 | |
| F-test exc. instruments (p-value) | | | 0.000 | | 0.000 | | | | 0.000 | | 0.000 | |
| Anderson LR statistic (p-value) | | | 0.000 | | 0.000 | | 0.000 | | 0.000 | | 0.000 | |
| Hansen's J statistic (p-value) | | | - | | - | | 0.192 | | 0.254 | | 0.207 | |

*Notes*: (1) OLS and IV estimates with individual fixed effects; $SO_2$ concentration is instrumented with the effect of flue gas desulfurization at power plants estimated with a distance decay modeled as an indicator function in specifications II and V and modeled with an exponential function in specifications III and VI; household income is instrumented with the sum of predicted incomes of the household members and job tenure of household of the primary/secondary wage earner in specifications IV, V and VI. (2) Standard errors are adjusted for clustering on county and year level. (3) ** is significant at the 99% level, * at the 95% level, and $^{(*)}$ at the 90% level.

with the picture that emerges from the difference in the magnitude of conventional and instrumented pollution effects (or rather our interpretation thereof). The ultimate source of concern is a potential correlation between pollution and unobservable characteristics, but local economic activity as captured by local unemployment seems not to bias conventional estimates.

The results in table 6 imply that TSP concentration is only weakly associated with life satisfaction. However, we do not dwell on these estimates as they may be afflicted by similar simultaneity problems as we conjecture in the case of conventional $SO_2$ estimates. Local unemployment rates have large negative effects even though we control for respondents' own employment status, a result that is consistent with earlier findings (Di Tella, MacCulloch and Oswald 2001; 2003). The results in the first stage regressions are as expected: TSP and $SO_2$ concentrations are positively associated, unemployment rates and $SO_2$ concentrations negatively.

Although unemployment rate and general air pollution drop from the list of potential candidates, there may be other (unobserved) predictors of life satisfaction that are correlated with $SO_2$ pollution. Therefore, we interact $SO_2$ with dummy variables for sub-groups of the population that are expected to suffer disproportionately from exposure to $SO_2$ pollution. In this way, the relatively insensitive group controls for other simultaneous and spatially coincident shocks. We consider two such pollution-sensitive groups: environmentally conscious or concerned individuals and individuals who are at risk with regard to adverse health effects from air pollution. The only variable in the GSOEP for environmental attitudes available in all years asks respondents whether they worry about environmental protection. Possible answers are "very concerned", "somewhat concerned" and "not concerned". Table 7 tabulates the number of observations in each category against deciles of $SO_2$ concentration. The number of very concerned people increases with pollution levels and the number of unconcerned people decreases. Of course, for environmental concerns to be a channel through which air pollution affects life satisfaction, such a positive relationship between objective and perceived environmental degradation is a necessary condition. Although only a few Germans characterize themselves as unconcerned, there are still 1,561 observations in the least populated cell ($10^{th}$ decile of $SO_2$ concentration · unconcerned respondents). The distribution of answers and pollution levels thus allows an implementation of the proposed empirical test.

*Table 7*. $SO_2$ pollution and environmental concerns, Germany 1985-2003

| $SO_2$ deciles | Environmental concerns | | | |
|---|---|---|---|---|
| | Very concerned | Somewhat concerned | Not Concerned | Total |
| 1st | 5,261 | 13,864 | 3,464 | 22,589 |
| 2nd | 5,338 | 13,590 | 3,240 | 22,168 |
| 3rd | 6,074 | 14,146 | 2,909 | 23,129 |
| 4th | 6,593 | 13,734 | 2,717 | 23,044 |
| 5th | 7,765 | 12,452 | 2,199 | 22,416 |
| 6th | 9,187 | 11,698 | 1,652 | 22,537 |
| 7th | 10,765 | 10,567 | 1,471 | 22,803 |
| 8th | 11,617 | 9,629 | 1,566 | 22,812 |
| 9th | 11,387 | 9,592 | 1,548 | 22,527 |
| 10th | 10,834 | 10,194 | 1,561 | 22,589 |
| Total | 84,821 | 119,466 | 22,327 | 226,614 |

Hospitalization and disability status are the only health variables in the GSOEP available in all years. These variables are not suitable for capturing pollution related health effects. Further, on a conceptual level, we are interested in identifying individuals belonging to a risk group rather than actually ill ones. In an auxiliary logit regression, we regress a dummy variable indicating persons suffering from chronic illnesses on a set of 24 *sex · age category* dummies and 24 corresponding interaction terms with $SO_2$ concentration. The dependent variable is the binary response to the question whether respondents suffered at least one year or chronically from specific complaints or illnesses, asked in the early waves of the GSOEP; this variable comes closest to representing respiratory and cardiovascular diseases caused by pollution. Using the estimated coefficients, we predict hypothetical probabilities of illnesses upon exposure to high and low pollution levels. We then classify individuals with a predicted difference in the probability of illness between high and low pollution situations that lies in the highest quartile as belonging to the high risk groups, and individuals with a predicted difference in the probability of illness that lies in the third quartile as belonging to the risk group. Table 8 reports the average effects of $SO_2$ concentration on the life satisfaction in the various subgroups.

*Table 8*. Interaction effects: Effect of $SO_2$ pollution on life satisfaction for different groups

| *Dependent Variable* | I | | II | |
|---|---|---|---|---|
| Life satisfaction | Coef. | t-value | Coef. | t-value |
| *Pollution and interaction terms* | | | | |
| $SO_2$ ($\mu g/m^3$) | -0.001 | -0.61 | -0.004** | -5.28 |
| $SO_2$ · somewhat concerned | -0.004** | -5.74 | | |
| $SO_2$ · very concerned | -0.005** | -5.89 | | |
| $SO_2$ · risk group | | | -0.002** | -3.00 |
| $SO_2$ · high risk group | | | -0.002** | -3.62 |
| *Environmentally concerned people and risk groups* | | | | |
| Not concerned at all | Reference group | | | |
| Somewhat concerned | -0.053** | -3.38 | | |
| Very concerned | -0.085** | -4.85 | | |
| Not in risk group | | | Reference group | |
| Risk group | | | 0.017 | 1.37 |
| High risk group | | | 0.071** | 4.82 |
| *HH income* | | | | |
| ln(post govt. income) | 0.139** | 16.78 | 0.140** | 14.94 |
| HH $size^{1/2}$ | -0.172** | -9.28 | -0.165** | -7.74 |
| *Personal characteristics* | Yes | | Yes | |
| *City, district size* | Yes | | Yes | |
| *State specific effects* | Yes | | Yes | |
| *State specific time trends* | Yes | | Yes | |
| *Year specific effects* | Yes | | Yes | |
| *Individual specific effects* | Yes | | Yes | |
| Number of observations | 226,614 | | 227,789 | |
| Number of individuals | 33,807 | | 33,864 | |
| Avg. no. of obs. per individual | 6.7 | | 6.7 | |
| Number of clusters | 7,410 | | 7,413 | |
| Prob > F | 0.000 | | 0.000 | |
| $R^2$ within | 0.038 | | 0.037 | |
| $R^2$ between | 0.008 | | 0.065 | |
| $R^2$ overall | 0.004 | | 0.055 | |
| Marginal effect of $SO_2$ for | M.E. | St. Err. | M.E. | St. Err. |
| Not concerned at all | -0.0005 | 0.0008 | | |
| Somewhat concerned | -0.0048** | 0.0007 | | |
| Very concerned | -0.0050** | 0.0007 | | |
| Not in risk group | | | -0.0039** | 0.0007 |
| Risk group | | | -0.0054** | 0.0008 |
| High risk group | | | -0.0061** | 0.0008 |

*Notes*: (1) OLS with individual fixed effects. (2) Standard errors are adjusted for clustering on county and year level. (3) ** is significant at the 99% level, * at the 95% level, and (*) at the 90% level.

The effect of air pollution on life satisfaction is monotonically increasing in the degree to which individuals are concerned about the environment and in the degree they are expected to suffer adverse health consequences from pollution exposure (see bottom rows of table 8). However, the 95% confidence intervals of the point estimates overlap except for unconcerned individuals for whom we find no effect of air pollution.

To sum up our results: First and most importantly, we find negative effects of $SO_2$ concentration on life satisfaction. The magnitude of the effect is larger for the instrumental variables estimates than for the conventional estimates. This difference suggests that pollution is accompanied by factors with a countervailing effect on life satisfaction. Even though an obvious candidate is local economic activity, it is not local unemployment but rather some other unobserved factor. The effects are robust to the inclusion of local unemployment rate and TSP concentration. Finally, differential effects for different groups of respondents imply that it is indeed air pollution that affects life satisfaction and not other simultaneous and spatially coincident shocks.

### 3.4 Effect on housing rents

#### 3.4.1 Data and empirical strategy

In order to calculate the total *WTP* for air quality, we supplement the results of the life satisfaction approach with housing hedonics for the same period and geographical area.[26] The following hedonic housing analysis is also based on the GSOEP. Household identifiers and information on moving dates of households allow us to build a panel at the dwelling level. The hedonic housing regressions are based on a panel for the period 1985-2003 consisting of 17,291 housing units with an average length in the panel of 3.7 years.

In contrast to the majority of hedonic market studies, we use rental prices instead of house prices, a deviation that seems justified in the present case for several reasons, in addition to data availability. First, as the life satisfaction approach, hedonic rent regressions yield *WTP* estimates in the form of (annually) recurring payments. Hence, in summing and comparing

[26] The standard hedonic framework assumes that individuals are compensated in the housing and the labor market for exposure to air pollution. However, as in previous studies, we find no effect of air quality on wages (e.g. Chay and Greenstone 2005; Bayer, Keohane and Timmins 2006). Thus, we only report the hedonic housing regressions.

estimates based on the two approaches, no assumptions on individuals' discount rates are necessary. Second, expected changes in air quality are capitalized into sales prices but not into current rents. Given that we have a panel with annual data and the major air quality regulation were enacted before our sample period, capitalized expectations would bias our estimates downwards or make it impossible to establish an effect of pollution on house prices. Third, in contrast to other countries, Germany has a well-developed, and relatively loosely regulated, market for rental housing. Nearly 60% of the households live in rented dwellings (compared to around 30% in the United States). Rents for vacant dwellings can be freely negotiated between landlords and potential tenants. There are some restrictions on evicting sitting tenants and a ceiling on rent increases for sitting tenants (up to 30% in a three-year period), but this ceiling is generally not binding (Hoffmann and Kurz 2002). An exception are subsidized dwellings, which are subject to comparatively strict regulation.

As a rule, hedonic housing regressions include a large number of time-invariant housing characteristics. With panel data, these characteristics can be captured by dwelling specific fixed effects (see e.g. Mendelsohn 1992; Gayer, Hamilton and Viscusi 2002 for repeat sale models). In accordance with the life satisfaction regressions, we control for state specific time trends and year effects.[27] Economic theory provides no a priori reason to prefer one functional form for the hedonic price function over others (Rosen, S. 1974). However, in general, when variables are omitted or replaced by proxies, simple forms outperform more flexible ones (Cropper, Deck and McConnell 1988). Therefore, we estimate semi-log hedonic rent regressions as specified in equation 8:

$$\ln(R_{icst}) = \beta_0 + \beta_1 P_{cst} + \beta_2 trend_s + \tau_t + o_i + \varepsilon_{icst}, \tag{8}$$

where $R_{icst}$ is the rent of dwelling $i$ in county $c$ and state $s$ at time $t$, $P_{cst}$ $SO_2$ pollution, $trend_s$ state specific time trends, $\tau_t$ and $o_i$ time and dwelling specific fixed effects, and $\varepsilon_{icst}$ the error term. Robust standard errors are adjusted for clustering on county and year level.

We exclude from our sample owner-occupied houses, even though the GSOEP provides owner estimates of rents. It might well be that owners may just convert their estimates of the house price into a rent estimate, with associated problems of capitalized expectations and sys-

[27] State specific fixed factors are captured by the dwelling fixed effects.

tematic biases in owners' appraisals (Ihlanfeldt and Martinez-Vazquez 1986). We further exclude subsidized dwellings because of the stricter regulations and, for obvious reasons, institutional households such as nursing homes and barracks as well as dwellings with an unknown ownership status.

### 3.4.2 Results

Table 9 presents the hedonic housing regressions in the same sequence as the life satisfaction results, i.e. column I presents the conventional estimates, and columns II and III the instrumental variable estimates (with the estimated effect of flue gas desulfurization based on an indicator and on an exponential distance decay function, respectively, as instruments); columns IV to VI show the corresponding results with TSP concentration and unemployment as additional control variables.

Pollution has a negative effect on housing rents. However, the results for the instrumental variable estimates do not allow us to draw any firm conclusions. The conventional estimate lies between the instrumental variable estimates. Therefore, it is not clear whether the conventional estimate is biased in one or the other direction. Further, the instrumental variable estimates are not robust to the inclusion of TSP concentration and local unemployment. The first estimate halves in size, the second completely collapses. Given the difference in the magnitude and the lacking robustness of the instrumental variable estimates, we do not favor one estimate over the others. Thus, the two instrumental variable estimates reported in columns II and III delimit the lower and upper bounds. Of course, one can also see the zero-effect implied by the result in column IV as an alternative upper bound. In the latter case, the conclusion that the housing market inadequately reflects the benefits of clean air is even stronger. According to our results, TSP concentration has a negative effect on housing rents and, contrary to prior expectations, local unemployment a positive effect.

*Table 9*. Hedonic housing regression: Effect of $SO_2$ pollution on monthly rents, Germany 1985-2003

| **A. Second stage regression** | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Dependent Variable* | I | | II | | III | | IV | | V | | VI | |
| ln(monthly rent), 2002 euro | Coef. | z-value | Coef. | z-value | Coef. | z-value | Coef. | z-value | Coef. | z-value | Coef. | z-value |
| *Pollution* | | | | | | | | | | | | |
| $SO_2$ ($\mu g/m^3$) | -0.009 ** | -9.36 | -0.010 ** | -4.98 | -0.003 (*) | -1.80 | -0.008 ** | -8.71 | -0.005 * | -2.09 | 0.002 | 1.36 |
| TSP ($\mu g/m^3$) | | | | | | | -0.002 ** | -5.49 | -0.003 ** | -5.66 | -0.004 ** | -7.57 |
| *Unemployment rate* | | | | | | | 0.058 ** | 15.01 | 0.060 ** | 15.10 | 0.065 ** | 15.69 |
| *State specific time trends* | Yes | | Yes | | Yes | | Yes | | Yes | | Yes | |
| *Year specific effects* | Yes | | Yes | | Yes | | Yes | | Yes | | Yes | |
| *Dwelling specific effects* | Yes | | Yes | | Yes | | Yes | | Yes | | Yes | |
| Prob > F | | 0.000 | | 0.000 | | 0.000 | | 0.000 | | 0.000 | | 0.000 |
| $R^2$ within | | 0.527 | | 0.527 | | 0.514 | | 0.546 | | 0.542 | | 0.512 |
| $R^2$ between | | 0.000 | | 0.000 | | 0.016 | | 0.005 | | 0.015 | | 0.037 |
| $R^2$ overall | | 0.001 | | 0.002 | | 0.008 | | 0.001 | | 0.007 | | 0.026 |
| **B. First stage regressions** | | | | | | | | | | | | |
| *Dependent Variable* | | | | | | | | | | | | |
| $SO_2$ ($\mu g/m^3$) | | | | | | | | | | | | |
| *Excluded instrument* | | | | | | | | | | | | |
| Predicted $\Delta SO_2$ | | | -0.322 ** | -12.81 | -0.283 ** | -16.56 | | | -0.278 ** | -11.48 | -0.251 ** | -15.17 |
| *Included instruments* | | | Yes | | Yes | | Yes | | Yes | | Yes | |
| Number of observations | | 64,651 | | 64,651 | | 64,651 | | 64,651 | | 64,651 | | 64,651 |
| Number of dwellings | | 17,291 | | 17,291 | | 17,291 | | 17,291 | | 17,291 | | 17,291 |
| Avg. no. of obs. per individual | | 3.7 | | 3.7 | | 3.7 | | 3.7 | | 3.7 | | 3.7 |
| Number of clusters | | 7,109 | | 7,109 | | 7,109 | | 7,109 | | 7,109 | | 7,109 |
| Shea's partial $R^2$ for $SO_2$ | | | | 0.032 | | 0.040 | | | | 0.024 | | 0.032 |
| Bound et al. partial $R^2$ | | | | 0.032 | | 0.040 | | | | 0.024 | | 0.032 |
| F-test exc. instruments (p-value) | | | | 0.000 | | 0.000 | | | | 0.000 | | 0.000 |
| Anderson LR statistic (p-value) | | | | 0.000 | | 0.000 | | | | 0.000 | | 0.000 |

*Notes*: (1) OLS and IV estimates with individual fixed effects; $SO_2$ concentration is instrumented with the effect of flue gas desulfurization at power plants estimated with a distance decay modeled as an indicator function in specifications II and V and modeled with an exponential function in specifications III and VI. (2) Standard errors are adjusted for clustering on county and year level. (3) ** is significant at the 99% level, * at the 95% level, and (*) at the 90% level.

3.5 Implicit willingness-to-pay

With the estimated coefficients of the micro-econometric life satisfaction functions for air pollution ($\hat{\beta}_1$) and household income ($\hat{\beta}_2$), we can calculate the hypothetical *WTP* for improvements in air quality or implicit utility-constant trade-offs between pollution and income. We measure the *WTP* by the compensating surplus (*CS*). The *CS* is the decrease in income necessary to hold utility constant if air quality improves. In other words, the *CS* is the solution to the following expression:

$$v(m_{i0};\, P_{i0}) = v(m_{i0} - CS;\, P_{i1}), \tag{9}$$

where $v(\cdot)$ is the utility function, $m_{i0}$ is the (initial) household income, $P_{i0}$ the initial level of air pollution and $P_{i1}$ the level after a hypothetical reduction. Given the specification of the micro-econometric life satisfaction functions expressed in equation 7, the *CS* for an improvement in air quality from $P_{i0}$ to $P_{i1}$, $\Delta P_i$, is defined as follows:

$$CS = m_{i0}(1 - \exp(\hat{\beta}_1 \cdot \hat{\beta}_2^{-1} \cdot \Delta P_i)). \tag{10}$$

Based on equation 10, the *WTP* can be calculated for marginal and inframarginal changes in air quality. We will add these estimates to the price gradients in order to calculate the total *WTP* for improvements in air quality.

In order to increase the comparability of the results of the life satisfaction approach and the hedonic method, we calculate the *WTP* for the households contained in the intersection of the two samples with average household income of € 21,462 and average rental costs of € 3,871 (in 2002 €). For both approaches, *MWTP* is expressed as annual household payments and is, therefore, directly comparable. The estimates are based on the coefficients reported in columns IV to VI of table 5 for the life satisfaction approach and on the coefficients in columns I to III of table 9 for the hedonic method. Standard errors are bootstrapped based on 1,000 repetitions. Table 10 presents the results. As usual, the conventional estimates are followed by two instrumental variable estimates (with the estimated effect of flue gas desulfurization based on an indicator distance decay function and based on an exponential distance decay function, respectively).

*Table 10. WTP* estimates for a reduction in air pollution

| | | | | | | |
|---|---|---|---|---|---|---|
| Average household income: | € 21,462 | | | | | |
| Average housing rent: | € 3,871 | | | | | |
| Compensating surplus | Life satisfaction approach estimates | | | Hedonic method estimates | | |
| | Conventional | Instrumental variable | | Conventional | Instrumental variable | |
| -1 μg/m$^3$ $SO_2$ | | | | | | |
| In euro | € 195** | € 458** | € 275* | € 35** | € 38** | € 10** |
| | (€ 21) | (€ 157) | (€ 115) | (€ 1) | (€ 4) | (€ 3) |
| In percent of income | 0.9%** | 2.1%** | 1.3%* | 0.2%** | 0.2%** | 0.05%** |
| | (0.1%) | (0.7%) | (0.5%) | (0.005%) | (0.02%) | (0.02%) |
| -48 μg/m$^3$ $SO_2$ | | | | | | |
| In euro | € 7,590** | € 13,828* | € 9,893** | € 1,693** | € 1,830 | € 471** |
| | (€ 966) | (€ 2,741) | (€ 3,057) | (€ 49) | (€ 176) | (€ 151) |
| In percent of income | 35.4%** | 64.5%** | 46.2%** | 7.9%** | 8.5% | 2.2%** |
| | (4.5%) | (12.8%) | (14.2%) | (0.2%) | (0.8%) | (0.7%) |

*Notes*: (1) Standard errors are bootstrapped based on 1,000 repetitions. (2) ** is significant at the 99% level, and * at the 95% level.

We start the discussion with the *MWTP* for a reduction in $SO_2$ concentration of 1 $\mu g/m^3$. The results for the life satisfaction approach lie in the range of € 195 to € 458 or, in percent of household income, in the range of 0.9% to 2.1%. The implicit prices for clean air reflected in the housing market are much smaller and lie between € 10 and € 35 (or between 0.05% and 0.2% of household income). By summing the estimates from the two methods, we get total *MWTP* estimates in the range of € 230 and € 496 (1.1% and 2.3% of household income, respectively). Further, the results in table 10 suggest that only between 3.5% and 15.2% of the total effects of air quality are capitalized in the housing market. This seems to be a very low proportion. At the same time, *MWTP* estimates based on the life satisfaction approach seem rather high. Potential reasons for these related findings are discussed below.

In order to asses the validity of our own hedonic price estimates, table 11 presents 34 estimates of *MWTP* for 6 cities reported in 5 different studies. In light of the large literature using the hedonic method to value air quality, the number of studies may seem relatively small. However, none of the other studies we could locate can be considered because they either investigate the effect of TSP concentration (see Smith, V. K. and Huang 1995 for a meta-analysis) and other pollutants or because $SO_2$ pollution is measured in units for which no generally accepted conversion factor to $\mu g/m^3$ exists (see e.g. Ridker and Henning 1967).

Table 11 reveals a large variation in *MWTP* estimates. The median of all estimates is € 201, the mean € 483. If we concentrate our attention on the positive and statistically significant implicit marginal prices, median and mean coincide at € 487. With a real interest rate of around 2% per annum, a lump-sum payment of € 487 equals an annual *CS* of € 10 paid in perpetuity, i.e. the lowest *MWTP* based on the hedonic method in table 10. With a real interest rate of around 8% per annum, it equals an annual *CS* of € 38, the highest *MWTP* in table 10. Hence, our *MWTP* estimates based on the hedonic method are broadly comparable to the estimates published in the literature.

*Table 11*. *MWTP* estimates reported in the literature

| City | Period | *MWTP* for decrease of 1 µg/m$^3$ $SO_2$ | | Source |
|---|---|---|---|---|
| | | Reported | In 2002€ | |
| Boston, MA, US | 1971 | -$39 (n.s.) | -$184 | Li and Brown (1980) |
| | | $109 (n.s.) | $514 | |
| | | $121 (n.s.) | $570 | |
| Chicago, IL, US | 1964-1967 | -$22 | -$131 | Atkinson and Crocker (1987) |
| | 1974-1976 | $27 (n.s.) | $39 | Zabel and Kiel (2000) |
| | 1977-1979 | $12 | $18 | |
| | 1981-1983 | $51 (n.s.) | $75 | |
| | 1985-1987 | $139 | $203 | |
| | 1989-1991 | $51 (n.s.) | $74 | |
| | 1989-1990 | $327 | $490 | Chattopadhyay (1999) |
| | | $325 | $487 | |
| | | $384 | $575 | |
| | | $203 | $304 | |
| | | $369 | $554 | |
| | | $204 (n.s.) | $305 | |
| Denver, CO, US | 1974-1976 | $9 (n.s.) | $13 | Zabel and Kiel (2000) |
| | 1977-1979 | $339 (n.s.) | $495 | |
| | 1981-1983 | -$120 (n.s.) | -$175 | |
| | 1985-1987 | $4,843 (n.s.) | $7,074 | |
| | 1989-1991 | $248 (n.s.) | $363 | |
| Philadelphia, PA, US | 1974-1976 | $15 | $22 | |
| | 1977-1979 | $94 (n.s.) | $137 | |
| | 1981-1983 | -$8 (n.s.) | -$11 | |
| | 1985-1987 | -$3 (n.s.) | -$5 | |
| | 1989-1991 | $63 | $92 | |
| Washington, DC, US | 1974-1976 | -$24 (n.s.) | -$35 | |
| | 1977-1979 | -$14 | -$20 | |
| | 1981-1983 | $22 (n.s.) | $32 | |
| | 1985-1987 | $149 | $218 | |
| | 1989-1991 | $136 | $198 | |
| Seoul, KR | 1993 | $901 | $1,055 | Kim, Phipps and Anselin (2003) |
| | | $892 | $1,044 | |
| | | $886 | $1,037 | |
| | | $864 | $1,012 | |
| Median of all estimates | | | $201 | |
| Median of sign. and positive est. | | | $487 | |
| Average of all estimates | | | $483 | |
| Average of sign. and positive est. | | | $487 | |

*Note*: (n.s.) is not significant.

We also calculate the *WTP* for an inframarginal improvement in air quality of 48 $\mu g/m^3$, corresponding to the average total decrease in $SO_2$ concentration between 1985 and 2003 for the households in the West German sample and between 1991 and 2003 for the households in East German sample. Estimates based on the life satisfaction approach are between € 7,590 and € 13,828 or between 34.4% and 64.4% of annual household income. Implicit prices for clean air in the housing market are between € 471 and € 1,830 or between 2.2% and 7.9%. Total *WTP* estimates amount to between € 9,283 and € 15,658 (43.3% and 73.0% of annual household income, respectively). These results would imply that only between 4.5% and 18.2% of the effect of air pollution are reflected in the housing rents.

The comparably low implicit price for clean air in the housing market (relative to the overall effect) and the large absolute size of the life satisfaction approach estimates require discussion. The first finding can be explained by factors that result in an incomplete capitalization of the experienced effects of air pollution in housing markets such as mobility costs, biased risk perceptions and divergence of decision and experienced utility. Section 2.3.2 discusses these factors in detail and provides evidence to support their relevance. To recapitulate, the *WTP* estimates for clean air based on house price data but allowing for mobility costs of Polnisky and Rubinfeld (1977) and Bayer, Keohane and Timmins (2006) are around three times higher than conventional estimates. Similarly, Smith and Huang (1995) show that benefit estimates for improvement in air quality based on dose-response functions and on a summary value of mortality risk are around 4 times higher than benefit estimates based on hedonic studies. Of course, a mis-perception of the effects of air pollution may not be the only reason for this discrepancy. But a reduction in mortality risk is only one of the benefits of clean air. Reductions in morbidity risk, in material damages and improved visibility are others. Thus the discrepancy reported by Smith and Huang (1995) is likely to understate the actual degree of "undercapitalization". It is important to note that both reasons may be simultaneously present and contribute to an incomplete reflection of the benefits of clean air in private markets. Further, incomplete capitalization can possibly be explained by the divergence of decision and experienced utility. For example, when looking for an apartment, other housing characteristics may be more salient than regional air quality. If people underestimate future utility streams derived from intangible goods such as good health relative to utility streams derived from disposable

income (Frey and Stutzer 2004a), we would expect that the experienced utility losses from air pollution are inadequately reflected in housing rents.

A more prosaic reason for the low implicit price relative to the residual shadow benefit estimated with the life satisfaction approach is related to a crucial element of the life satisfaction approach, the estimation of the marginal utility of income. This same reason could also explain the high absolute estimates based on the life satisfaction approach. For two reasons, the (short-run) marginal utility of income may be underestimated in micro-econometric life satisfaction functions. First, instrumenting income is inherently difficult and our efforts may fall short of completely resolving the problems of endogeneity of income and omitted costs of income generation. Second, a growing body of literature demonstrates that relative motives play an important role. Individuals evaluate their income situation relative to the income of reference groups, own past income and income aspirations (see section 2.1 for references). If people adapt to changes in income, the long-run marginal utility of income understates the short-run utility consequences of income changes. Even if one can argue in favor of using the long-run marginal utility for policy evaluation (e.g. Kahneman and Thaler 1991; Loewenstein and Schkade 1999; Kahneman and Sugden 2005), (unexpected) adaptation can explain why *WTP* estimates based on the life satisfaction approach seem unreasonably high from a decision utility perspective. The realization of the importance of relative concerns has implications for all non-market valuation methods and may well speak in favor of the use of the life satisfaction approach instead of standard approaches. For example, Frank (2000) shows that positional concerns bias hedonic market estimates downward. Although the problems of estimating the marginal utility of income are discussed in the context of air pollution, they equally apply to the other applications in the next two chapters and to the life satisfaction approach in general. Investigating the relationship between income and life satisfaction is a fast growing area of research (see Clark, Frijters and Shields 2007 for a review). Therefore, better estimates of marginal utility of income will come forward. However, the problems of estimating the marginal utility of income correctly may also speak in favor of abandoning the practice of valuing public goods in monetary terms. This issue is discussed in more detail in section 6.1.3.

As we have seen, the problems associated with estimating the effect of income may make it difficult to give precise benefit estimates in monetary terms and to exactly establish the degree of incompleteness in the capitalization of the benefits in the housing market. However, in the

present case, at least two unambiguous conclusions can be drawn. First, the negative relationship between air pollution and life satisfaction indicates that individuals are not fully compensated in markets. Thus, while the life satisfaction approach may overstate benefits of clean air, the hedonic method clearly understates these benefits. Our results suggest that the difference may be large. Second, the evaluation of the large combustion plant ordinance in Germany is unambiguous. Whatever *WTP* estimate is chosen, the costs of flue gas desulfurization are dwarfed. Rough estimates of the private compliance costs (not social costs; see Hazilla and Kopp 1990) for Western Germany range between €35 and €180 per year and household.[28]

## 3.6 Appendix to chapter 3

This appendix provides a detailed description of the data on German power plants and wind directions used to estimate the causal effect of flue gas desulfurization on annual mean $SO_2$ concentrations at county level.

*Power plants*

The data for fossil fuel fired generating units with an electricity capacity of 100 MW and more are from several sources, namely the UBA, information published by the operating companies and the technical literature, a survey mailed to operating companies and statutory provisions. To a list of 396 generating units provided by the UBA, we add 56 units and then reduce the number of units to 390 by combining all units with identical location and characteristics. Of theses 390 units, 7 units have a capacity of less than 100 MW, 351 were active in the period 1985 to 2003 and 303 units were active and are neither nuclear or hydroelectric power plants. The UBA list contains information on the plant name, operator and/or owner, zip code of contact address (which does not necessarily correspond to the plant's location), the launching year, the year the plant was shut down, capacity and fuel. We complement the data with the location, the year of refit (desulfurization), fuel efficiency and estimates of annual $SO_2$ emissions.

[28] Schaerer and Haug (1990) put the cost of installation of scrubbers at West German power plants at DM 14.2 billion (1988 DM). Doubling this value to account for operation costs, assuming a real long-term interest rate of 5% and dividing by 27,793,000 households (living in Germany in 1989), gives an estimate of € 36 per household and year. Another estimate of desulfurization at power plants provided by Schaerer and Haug (1990) is DM 0.0075 per kWh of electricity produced. In 1989, West German power plants produced 452.39 billion kWh of electricity. The costs per household and year are therefore € 87. Finally, Schulz' (1985) most pessimistic cost estimate is DM 9 per household and month (1985 DM assumed) or € 179 per household and year. It is important to note that these estimates say nothing about the distribution of the costs.

Location: If possible, we establish the exact address using information published by the operating companies and in the technical literature, or a route planner. Otherwise, the centroid of the zip-code is assumed to be a plant's location. We georeference the addresses with a route planner.

Year of refit: Published information and responses to our survey of operating companies allows us to determine the year scrubbers were installed for 224 units (61%). For the other units the year can be approximated on the basis of statutory provisions, the launching year, the year the plant was shut down and the capacity.

Fuel efficiency ($\eta_j$): Published information and survey responses provide information on the fuel efficiency of 196 units (54%). For the other units fuel efficiency is predicted based on the following regression (t-values in parentheses):

$$\eta_j = \underset{(3.76)}{9.6\text{E-}4}\cdot start\ year_j + \underset{(6.98)}{9.9\text{E-}5}\cdot capacity_j - \underset{(-1.25)}{0.035}\cdot 1(lignite)_j + \underset{(0.27)}{0.008}\cdot 1(sub\text{-}bituminous\ coal)_j +$$
$$\underset{(1.98)}{0.054}\cdot 1(natural\ gas)_j - \underset{(-1.56)}{0.042}\cdot 1(HEL)_j + \underset{(2.32)}{0.079}\cdot 1(HS)_j - \underset{(-2.73)}{0.103}\cdot 1(uranium)_j + \underset{(4.03)}{0.185}\cdot 1(hydro)_j$$
$$\underset{(-1.72)}{-0.053}\cdot 1(mixed\ fuel)_j - \underset{(-3.37)}{0.027}\cdot 1(desox)_j + \underset{(5.39)}{0.056}\cdot 1(denox)_j - \underset{(-3.13)}{1.589}$$

$R^2 = 0.727$, Prob > F = 0.000

Emissions: In order to estimate annual $SO_2$ emissions, we use emission factors, *EF*, from a time shortly before scrubbers were installed (Bakkum et al. 1987). Emission factors are defined as the industry wide average ratio between the emission rate and the actual load differentiated according to fuel and capacity. Assuming full utilization of capacities, the annual emission at plant *j*, $E_j$, can be estimated as

$E_j = EF(fuel, capacity)\cdot capacity_j \cdot \eta_j^{-1} \cdot time\ period$ (31,536,000 seconds).

This calculation overstates emissions because the assumption of constant full utilization is not plausible but as we lack data on utilization rates, we cannot estimate the emissions more accurately. Moreover, the procedure allows us to capture the important differences in emissions between fuels and plant sizes.

*Wind stations*

Frequencies of wind directions in 12 30-degree sectors measured at wind stations are published in Traup and Kruse (1996). The wind atlas contains data on 107 wind stations of which 12 are not representative for a larger area. For each power plant the wind station closest to the plant is used to describe the wind situation at the plant, restricting the number of wind stations to 43. The frequency distributions are based on measurement series of at least 5 years, in most cases 15 years and in some cases more than 15 years in the period between 1976 and 1995.

*Well, before the flood I was happy.*
Victim of the Bufallo Creek flood, West Virginia, in 1872, cited in Erikson (1976, p. 223)

## 4. Application to flood disasters

### 4.1 Introduction

Regarding natural disasters, the last years have often been described as *anni horribili*. The tsunami in the Indian Ocean, Hurricane "Katrina" on the U.S. Gulf Coast and the Pakistan earthquake are the most prominent catastrophes of the recent past. In Europe, floods rank highest among natural disasters. During the past two decades, several extreme floods have occurred in Central European rivers (including the Rhine, Danube, Odra, and Wisla), culminating in the disastrous August 2002 flood in the Elbe River basin and parts of the Danube basin. Likewise, the U.S. Federal Emergency Management Agency (FEMA) calls flooding "America's #1 Natural Hazard" (FEMA 2004). And more is to be expected! Climate-induced changes in the timing of runoff for several European river basins and small Alpine catchments increase the risk of winter floods (Schröter et al. 2005). Dramatic increases in flood frequency and intensity are also likely in parts of the United States (e.g. Gleick 1999). Questions regarding the financing of flood protection and prevention strategies are likely to rise in significance on the political agenda. Therefore, it is important to assess the utility losses caused by natural disasters. Moreover, the increase in risk raises the question to what extent risk transfer mechanisms such as (mandatory) catastrophe insurance can mitigate the effects of disasters. The higher the non-insurable psychic costs are, the less relief such a system will provide.

This chapter has two major objectives. First, we use the life satisfaction approach to measure the utility consequences caused by flood hazards for 17 OECD countries between 1973 and 2004. The analysis comprises 127 major flood events and spatial data on flood hazard distribution. Both variables exhibit large variation across countries and regions. Second, in an explorative analysis, we investigate whether and to what extent risk transfer mechanisms mitigate the adverse effects of flood disasters.

Before presenting the analysis, it might be helpful to shortly reflect on how flood disasters can affect individual life satisfaction. Two broad categories of flood effects can be distinguished: financial or property losses and psychic costs. The most important effects of the first category

are property damages. Additionally, reconstruction efforts affect government budgets and have tax consequences for the individuals. With regard to the psychic costs, three different effects are discussed in the literature. First, there is the grief of the bereaved and, more generally, altruistic sympathy with the victims. Both are likely to be a function of distance and those in affected regions are more likely to know people directly affected (Kimball et al. 2006). Second, flood victims may suffer from individual trauma or from some combination of anxiety, depression, insomnia, apathy and bad nerves. Third, there may be what Erikson (1976, pp. 153-154) calls collective trauma: "[…] a blow to the basic tissues of social life that damages the bonds attaching people together and impairs the prevailing sense of communality", "[…] the realization that the community no longer exists as an effective source of support and that an important part of the self has disappeared."

### 4.2 Flood hazards: Data and pattern

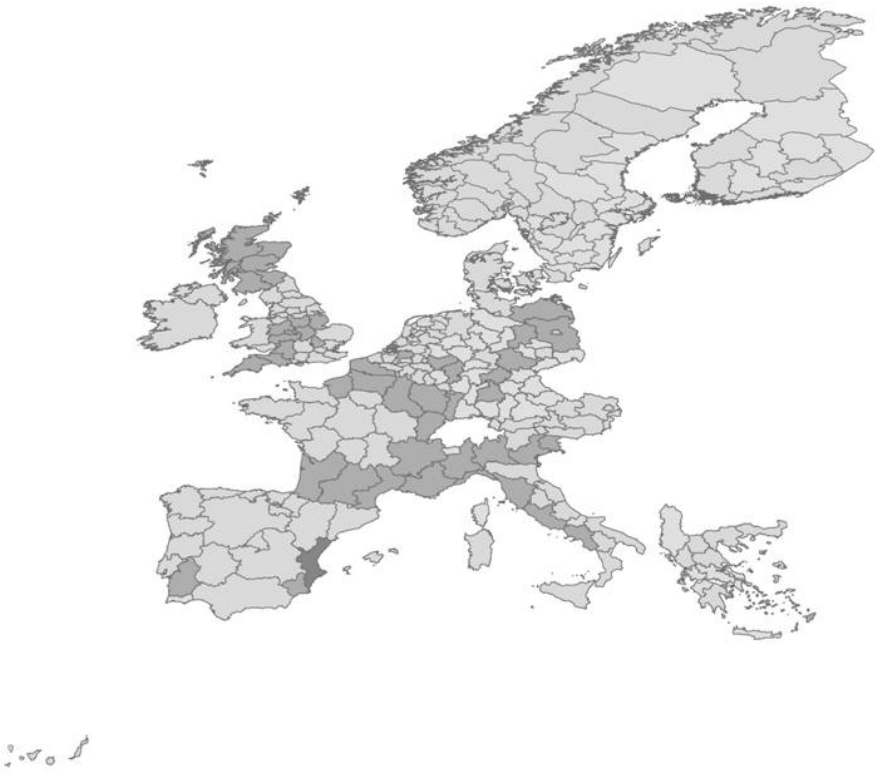
As explained in section 2.4.3, we match the flood data to the survey data on the lowest geographical level that ensures a consistent definition across countries and over time. For European countries this is the middle level of the official territorial units for statistics of the EU, the NUTS II. The definition of the NUTS regions is based on actual administrative boundaries or institutional divisions in the EU member states. Therefore, the size of the regions slightly differs across countries. For the United States, the data are matched on the level of counties.

We use two different variables for flood hazards. The first captures actual flood events, the second contains spatial information on the flood exposure of the regions. The data on flood events are from the most comprehensive data set on disasters, the EM-DAT of the Centre for Research on the Epidemiology of Disasters (CRED). In order to be included in EM-DAT, a disaster has to fulfill one of the following criteria: 10 or more people reported killed, 100 people reported affected, declaration of a state of emergency or call for international assistance. Hence, flood events that occurred in thinly populated areas are not included in the database and in the analysis. Based on this database we create a dummy variable that takes on the value 1 for all respondents living in a region hit by a flood disaster in the 12 month preceding the interview and 0 otherwise. We have a total of 127 floods in our sample, 56 in 11 European countries and 71 in the United States. Of the 473 regions in our sample, 369 regions experienced no flood at all in the period considered, 88 experienced 1 flood, 12 experienced 2 floods, and 4 experienced 3 floods. In Europe, around 9% of all regions were afflicted by a flood event in the sample period, in the United States around 17% of the counties. Figure 4

depicts the number of flood events per region divided by the number of years each region is in the sample.

*Figure 4*. Number of floods per annum

A. Europe, 1973-1998



B. United States, 1993-2004

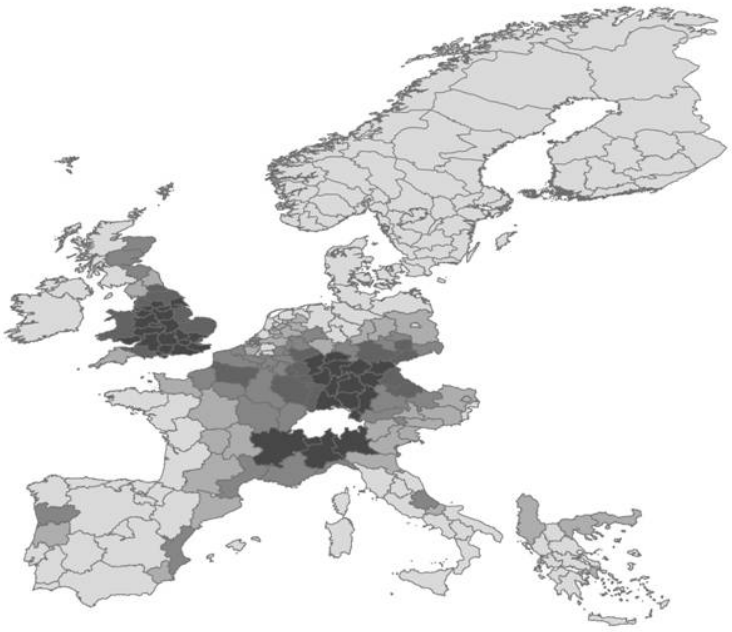
*Legend:* 0.00, 0.01 – 0.17, 0.18 – 0.20, 0.21 – 0.29 and 0.30 – 0.40.

*Source*: EM-DAT, Centre for Research on Epidemiology of Disasters (CRED), own estimates.

The data on flood hazard areas is based on a study by the World Bank and Columbia University (Dilley et al. 2005) that identifies global natural disaster hotspots. Data on historical flood disasters from 1985 to 2003 collected by the Dartmouth Flood Observatory are georeferenced and then combined in a grid with cell size of 1º · 1º. Depending on the number of georeferenced floods, cells have values between 0 and 10. Using these grid data and polygon data describing the boundaries of the regions in our sample, we calculate the mean value of the grid cells within each region. The GIS data have some limitations. First, the data identify regions affected by floods and not the exact flooded areas. Second, data on events in the early 1990s are missing or of low spatial quality. However, the GIS data is the best (publicly) available data on flood hazard areas at such an aggregated level that has been collected and processed with a uniform method. The maps in figure 5 present the regional mean flood exposure for Europe and the United States.

*Figure 5*. Flood hazard distribution, regional mean values

A. Europe



*To be continued*.

*Figure 5*, part 2

B. United States

*Legend:* 0.00 – 2.00, 2.01- 5.00, 5.01 – 7.00, 7.01 – 8.00 and 8.01 – 10.00.
*Source:* Dilley et al. (2005), own estimates.

The mean flood exposure of the European countries in the sample is 2.05; the mean flood exposure for the counties of the United States in our sample is 5.10. Table 12 provides descriptive statistics of our two flood variables at the national level.

*Table 12*. Flood disasters and flood hazard distribution in 16 European countries and the United States, 1973-2004

| Country | No. of regional flood disasters | | | Hazard distribution | |
|---|---|---|---|---|---|
| | Total | Per annum | Std. Dev. | Mean | Std. Dev. |
| Austria | 0 | 0.00 | 0.00 | 3.909 | 2.465 |
| Belgium | 2 | 0.09 | 0.02 | 5.879 | 1.990 |
| Denmark | 0 | 0.00 | 0.00 | 0.000 | 0.000 |
| Finland | 0 | 0.00 | 0.00 | 0.000 | 0.000 |
| France | 15 | 0.69 | 0.04 | 4.363 | 3.581 |
| Germany | 11 | 0.66 | 0.06 | 5.368 | 3.591 |
| Greece | 1 | 0.07 | 0.02 | 1.238 | 1.588 |
| Ireland | 1 | 0.05 | 0.03 | 0.684 | 1.209 |
| Italy | 14 | 0.58 | 0.04 | 2.983 | 3.329 |
| Luxembourg | 1 | 0.05 | 0.00 | 7.587 | 0.493 |
| Norway | 0 | 0.00 | 0.00 | 0.061 | 0.140 |
| Portugal | 1 | 0.09 | 0.03 | 3.645 | 1.875 |
| Spain | 3 | 0.28 | 0.05 | 1.153 | 1.904 |

*To be continued*.

*Table 12*, part 2

| | | | | | |
|---|---|---|---|---|---|
| Sweden | 0 | 0.00 | 0.00 | 0.013 | 0.112 |
| The Netherlands | 0 | 0.00 | 0.00 | 3.032 | 1.795 |
| United Kingdom | 4 | 0.19 | 0.03 | 5.505 | 3.741 |
| USA | 71 | 16.65 | 0.09 | 4.843 | 0.500 |

*Notes*: (1) The actual number of floods per country is smaller. Some flood events are double counted as they have affected more than one region within a country. (2) The standard deviation for the number of flood disasters is calculated using the annual number of floods per region in a country. (3) The mean and standard deviation of the flood hazard distribution is calculated by using a polygon GIS-layer representing national boundaries.

## 4.3 Effects on life satisfaction

### 4.3.1 Data and empirical strategy

The individual-level data with information on respondents' subjective well-being and household income come from the EB for the 16 European countries and from the GSS for the United States. The EB interviews a cross-section sample of Europeans each year. The countries have been contained in the sample since the year of EU accession. For the United Kingdom, the first year (1973) is not considered because the regional variable is too coarse, for Spain no observations are available until 1986, and Norway is included in the sample in the years 1990 to 1995 even though it is not a member state. For all countries except Norway, the sample includes observations until 1998. Like the EB, the GSS is an annual cross-sectional survey of a nationally representative sample. Although it started in 1972, data on the county level have only been available since 1993. The last year in our sample is 2004.

For Europe, we exclude respondents below age 15; in the GSS the minimum age is 18. This leaves us with 328,610 observations for Europe and with 13,138 observations for the United States. In both datasets, missing income information contributes most to reducing the sample size. The number of observations for country-years varies between 152 for Luxembourg in 1988 and 6,014 for Germany in 1992; for region-years the number of observations varies between 1 and 1,455. In general, the number of observations per year is smaller for the counties in the United States than in the European regions. While there are 36 county-year combinations with only 1 observation in the United States, there are only 4 region-year combinations

with only 1 observation in Europe.[29] The median number of observations per region and year is 42, the mean is 89.

The variables capturing subjective well-being are similar in the two datasets, but not identical. In the EB, the variable is the categorical response to the following question: "On the whole, are you very satisfied [4], fairly satisfied [3], not very satisfied [2], or not at all satisfied [1] with the life you lead?" The question was asked in all years between 1973 and 1998, with the exception of the years 1974 and 1996. In the GSS the question reads "Taken all together, how would you say things are these days – would you say that you are very [4] happy, [3] pretty happy, or [2] not too happy?" While "life satisfaction" and "happiness" might be located at different points along the cognition-affect dimension capturing slightly different aspects of subjective well-being (see section 2.2.1), they are highly correlated and findings based on the two measures are similar (Di Tella and MacCulloch 2005a). In combining the two datasets, we follow Di Tella and MacCulloch (2005a). We simply add a first, lowest, category that is assumed to be empty to the happiness variable in the GSS. This resembles the actual distribution in the EB with only 7.2% of the answers in the bottom category. As an alternative method, we also collapse the two lowest categories in the EB. The findings are nearly identical for both methods.

Both datasets contain information on respondents' household income. In the EB, respondents are assigned into between 6 and 12 classes of household income. The class size and number of classes varies considerably between countries and surveys. Therefore, we translate the original income class information into a number, which represents the mid-point of the respective class interval. These values are converted into 2004 U.S. dollars. Because the highest income class is open-ended, respondents who fall into this income class are excluded. In the GSS, the originally grouped income data are already translated into real income in 2004 U.S. dollars (see

[29] The 36 county-year combinations in the United States are Pima, AZ, in 1993, Sacramento, CA, in 2004, San Francisco, CA, in 2004, Ventura, CA, in 2004, Jefferson, CO, in 2004, Hillsborough, FL, in 2004, Palm Beach, FL, in 2002, Pasco, FL, in 2004, De Kalb, GA, in 2002, DuPage, IL, in 2002, Henderson, KY, in 2002, Essex, MA, in 2002, Norfolk, MA, in 2004, Carroll, MD, in 2002, Montgomery, MD, in 2004, Prince George's, MD, in 2002, Baltimore city, MD, in 2002, Bay, MI, in 1998, Saginaw, MI, in 2000, Burke, NC, in 1994, Bergen, NJ, in 2004, Camden, NJ, in 2002, Hudson, NJ, in 2004, Monmouth, NJ, in 2002 and 2004, Passaic, NJ, in 2002, Union, NJ, in 1993 and 2004, Montgomery, PA, in 2002, Philadelphia, PA, in 1993, Jefferson, TN, in 2004, Bexar, TX, in 2004, Galveston, TX, in 1996, Chesterfield, VA, in 2002, Henrico, VA, in 2002, Hopewell, VA, in 2002. The 4 region-year combinations in Europe are Basse-Normandie, France, in 1983 and 1988, Poitou-Charentes, France, in 1988, Canaries, Spain, in 1986. The region-year combination with the highest number of observations is Jylland, Denmark, in 1992.

Ligon 1994). In order to capture the effect of household size on equivalence income, the square root of household size is included in the estimation equations. Further, we include a set of personal characteristics, including sex, age, marital status, number of children, employment status and type of community in which the respondent lives.[30] Repeated cross-section models are specified in combination with the variable on flood events, single cross-section models for the variable on flood hazard distribution. In the repeated cross-section analysis, the life satisfaction of individual $i$ living in region $r$ at time $t$, $LS_{irt}$, is explained by the occurrence of a flood disaster in region $r$ in the month of or in the 12 months preceding the interview, $F_{r(t\text{-}1,t]}$, the natural logarithm of the individual's household income, $\ln(m_{irt})$, a vector of personal characteristics, $Z_{irt}$, as well as region and time specific effects, $\rho_r$ and $\tau_t$. The specification is summarized in equation 11:

$$LS_{irt} = \beta_0 + \beta_1 F_{r(t\text{-}1,t]} + \beta_2 \ln(m_{irt}) + \beta_3 Z_{irt} + \rho_r + \tau_t + \varepsilon_{irt}. \quad (11)$$

The specification for the cross-section analysis is similar except for the flood hazard variable, which is now the regional mean of the flood hazard distribution, $H_r$, and for the omission of the region specific effects, which cannot be included. The specification becomes thus:

$$LS_{irt} = \beta_0 + \beta_1 H_r + \beta_2 \ln(m_{irt}) + \beta_3 Z_{irt} + \tau_t + \varepsilon_{irt}. \quad (12)$$

We estimate equations 11 and 12 by least square and, because of the ordinal nature of the dependent variable, by ordered probit regressions. The results are qualitatively and quantitatively very similar for the two estimation approaches. For ease of interpretation, results from least square regressions are presented. However, the *CS*s reported below are calculated on estimates on both kinds of regressions. Robust standard errors are adjusted for clustering at the level of regions and years in the repeated cross-section analysis and at the level of regions in the cross-section analysis.

The coefficient for actual events, $\beta_1$ in equation 11, captures all non-insured costs of flood disasters (see discussion in section 2.4.2). Therefore, we expect this coefficient to be negative.

[30] Note that respondents' education is not included in the vector of personal characteristics. Education is highly correlated with lifetime income and, therefore, likely to take away explanatory power from the income variable. Further, in order to translate the utility losses caused by flood disasters into monetary terms, the effect of income on life satisfaction per se rather than the effect of within-education variation in income is needed. However, the results are similar if income is controlled for.

The coefficient for flood exposure, $\beta_1$ in equation 12, on the other hand, captures all costs of flood exposure for which individuals are not compensated in the housing market. While theoretically it could be zero, we expect it to be negative.

### 4.3.2 Basic results

The main results are presented in table 13. Columns I to III contain the results of the repeated cross-sections, the columns IV to VI the results of the cross-sections. The results for the control variables are similar to earlier findings in happiness research in general and estimates based on the EB and the GSS in particular (Di Tella and MacCulloch 2005a).

Both actual events and the level of exposure to flood hazard have a negative effect on life satisfaction that is statistically significant. On average, a person living in a region that has been affected by a flood disaster, reports a 0.036 point lower life satisfaction on the 4-point scale compared to the reference group. As can be seen from columns II and III of table 13, we find in both sub-samples, the European and the American sub-sample, a negative effect of flood events on life satisfaction. Not surprisingly, given the small sample size of the American sub-sample, in the case of the United States the coefficient is not statistically significantly different from zero at conventional levels of significance and the coefficient for the whole sample is strongly influenced by the European sub-sample. The estimate for the United States is smaller in absolute terms compared to the estimates for the whole sample and for Europe. Turning to the cross-sectional estimates, we see that the increase of a region's flood exposure by 1 unit on the 10-point scale lowers life satisfaction on average by 0.02 points. A one standard deviation increase in flood exposure results in a loss of life satisfaction by 0.061 points. The magnitude of the effect of flood exposure on life satisfaction for the United States is only around 17% the magnitude of the effect for the whole sample and for Europe.

Income has a positive effect on individuals' life satisfaction that is statistically highly significant. In the repeated cross-section analysis, the partial correlation between income and subjective well-being is 0.180 for the whole sample. This implies that reported subjective well-being increases by 0.125 on average if household income is doubled. Regarding the size of the different coefficients across different models, two aspects are noteworthy: First, in Europe, the

*Table 13*. Basic results: Effect of flood hazards on life satisfaction, 16 European countries and the United States, 1973-2004

| *Dependent Variable* | I | | II | | III | | IV | | V | | VI | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Life satisfaction | All countries | | Europe | | United States | | All countries | | Europe | | United States | |
| | Coef. | t-value | Coef. | t-value | Coef. | t-value | Coef. | t-value | Coef. | t-value | Coef. | t-value |
| *Flood hazards* | | | | | | | | | | | | |
| Flood events | -0.036 ** | -2.65 | -0.037 ** | -2.59 | -0.025 | -0.94 | | | | | | |
| Flood distribution | | | | | | | -0.020 * | -2.46 | -0.021 * | -2.55 | -0.003 (*) | -1.97 |
| *HH income* | | | | | | | | | | | | |
| ln(HH income) | 0.180 ** | 50.57 | 0.189 ** | 48.32 | 0.084 ** | 12.29 | 0.308 ** | 14.87 | 0.328 ** | 14.96 | 0.084 ** | 12.12 |
| HH size$^{1/2}$ | -0.082 ** | 17.59 | -0.086 ** | -17.55 | -0.032 (*) | -1.90 | -0.215 ** | -7.66 | -0.226 ** | -7.59 | -0.033 * | -2.15 |
| *Personal characteristics* | | | | | | | | | | | | |
| Male | Reference group | | Reference group | | Reference group | | Reference group | | Reference group | | Reference group | |
| Female | 0.042 ** | 13.34 | 0.042 ** | 13.08 | 0.027 * | 2.48 | 0.033 ** | 3.91 | 0.033 ** | 3.74 | 0.028 * | 2.50 |
| Age | -0.019 ** | -35.06 | -0.019 ** | -34.23 | -0.012 ** | -5.06 | -0.021 ** | -20.00 | -0.021 ** | -19.67 | -0.012 ** | -5.00 |
| Age$^2$ | 2E-4 ** | 36.49 | 2E-4 ** | 35.75 | 1E-4 ** | 5.46 | 2E-4 ** | 22.59 | 2E-4 ** | 22.00 | 2E-4 ** | 5.28 |
| Single | Reference group | | Reference group | | Reference group | | Reference group | | Reference group | | Reference group | |
| Married | 0.079 ** | 18.53 | 0.074 ** | 17.18 | 0.251 ** | 13.27 | 0.067 ** | 5.53 | 0.065 ** | 5.21 | 0.259 ** | 14.36 |
| Separated | -0.225 ** | -17.14 | -0.231 ** | 16.26 | -0.112 ** | -3.70 | -0.200 ** | -11.07 | -0.209 ** | -11.01 | -0.116 ** | -3.54 |
| Divorced | -0.146 ** | -18.02 | -0.153 ** | -17.04 | -0.023 | -1.10 | -0.109 ** | -7.67 | -0.110 ** | -6.61 | -0.018 | -0.98 |
| Widowed | -0.097 ** | -15.16 | -0.096 ** | -14.56 | -0.072 ** | -2.60 | -0.099 ** | -11.17 | -0.095 ** | -10.27 | -0.066 ** | -2.41 |
| No children in HH | Reference group | | Reference group | | Reference group | | Reference group | | Reference group | | Reference group | |
| One child | -0.003 | -0.55 | 0.01 | 0.12 | -0.076 ** | -4.03 | 0.010 | 1.42 | 0.014 (*) | 1.85 | -0.081 ** | -4.19 |
| Two children | 0.011 (*) | 1.79 | 0.012 (*) | 1.69 | -0.038 * | -2.10 | 0.071 ** | 6.12 | 0.078 ** | 5.65 | -0.039 * | -2.19 |
| Three children | 0.014 | 1.42 | 0.013 | 1.07 | -0.036 (*) | -1.75 | 0.124 ** | 7.41 | 0.144 ** | 6.90 | -0.037 (*) | -1.76 |
| Four and more children | -0.014 | -0.99 | -0.036 (*) | -1.80 | -0.050 * | -2.15 | 0.130 ** | 5.76 | 0.169 ** | 4.89 | -0.053 * | -2.36 |
| Employed or self-employed | Reference group | | Reference group | | Reference group | | Reference group | | Reference group | | Reference group | |
| Other occupation | 0.050 ** | 4.12 | 0.072 ** | 5.44 | -0.122 ** | -4.22 | 0.159 ** | 6.67 | 0.199 ** | 7.67 | -0.122 ** | -4.16 |
| Housekeeping | 0.005 | 1.32 | 0.007 | 1.62 | -0.016 | -0.81 | 0.048 ** | 3.13 | 0.051 ** | 3.31 | -0.013 | -0.67 |

*To be continued.*

*Table 13*, part 2

| | I<br>All countries | | II<br>Europe | | III<br>United States | | IV<br>All countries | | V<br>Europe | | VI<br>United States | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Coef. | t-value | Coef. | t-value | Coef. | t-value | Coef. | t-value | Coef. | t-value | Coef. | t-value |
| Retired | 0.015 ** | 2.66 | 0.015 ** | 2.71 | 0.005 | 0.19 | 0.010 | 0.74 | 0.009 | 0.69 | 0.001 | 0.03 |
| In education | 0.114 ** | 17.25 | 0.116 ** | 17.10 | 0.030 | 0.83 | 0.136 ** | 8.40 | 0.144 ** | 8.24 | 0.042 | 1.21 |
| Unemployed | -0.316 ** | -37.74 | -0.315 ** | -37.14 | -0.183 ** | -4.87 | -0.266 ** | -11.37 | -0.261 ** | -10.97 | -0.194 ** | -5.31 |
| Living in rural area | Reference group | | Reference group | | Reference group | | Reference group | | Reference group | | Reference group | |
| Living in a small town | -0.030 ** | -7.58 | -0.031 ** | -7.79 | -0.001 | -0.01 | -0.050 ** | -3.76 | -0.053 ** | -3.96 | 0.010 | 0.41 |
| Living in a big town | -0.081 ** | -15.66 | -0.082 ** | -15.87 | 0.001 | 0.01 | -0.129 ** | -4.44 | -0.132 ** | -4.47 | -0.056 * | -2.27 |
| *Region specific effects* | Yes | | Yes | | Yes | | No | | No | | No | |
| *Year specific effects* | Yes | | Yes | | Yes | | Yes | | Yes | | Yes | |
| *Constant* | Yes | | Yes | | Yes | | Yes | | Yes | | Yes | |
| Number of observations | 341,748 | | 328,610 | | 13,138 | | 341,748 | | 328,610 | | 13,138 | |
| Number of clusters | 3,854 | | 2,569 | | 1,285 | | 478 | | 172 | | 306 | |
| Prob > F | n.a. | | 0.000 | | n.a. | | 0.000 | | 0.000 | | 0.000 | |
| $R^2$ | 0.186 | | 0.186 | | 0.121 | | 0.100 | | 0.102 | | 0.098 | |

*Notes*: (1) OLS estimates. (2) Standard errors are adjusted for clustering on level of regions and years (repeated cross-section) and on the level of regions (cross-section). (3) ** is significant at the 99% level, * at the 95% level, and (*) at the 90% level.

coefficient for income is around 70% higher in the cross-sectional compared to the combined cross-section and time-series analysis. As we will see below, this difference is driven by cross-country differences. Once we control for nation specific effects, the effect of income in the cross-sectional analysis becomes very similar to the effect in the combined cross-section and time-series analysis. Second, the effect of income in the United States is around 44% of the estimate for Europe. It is, however, similar in the cross-section and the combined cross-section and time-series analysis. The coefficients for the flood variables as well as the coefficient for income are smaller in the American sample than the European sample. As the coefficients for the flood variables and for income exert countervailing effects on implicit *WTP*, the overall effect of the differences between Europe and the United States is open. Anticipating the results, implicit *WTP* in percent of household income for the United States is around 50% higher than in Europe.

### 4.3.3 Robustness tests

We perform two robustness tests. First, increased occurrence of flood disasters often afflicts European regions that experienced structural change and economic decline. Therefore, we include variables capturing the state of the regional economy, namely growth rates of GDP per capita and the unemployment rate. Because we need regional data for a large number of countries and years, the availability of other control variables is severely restricted.

It is important to note that a decrease in the coefficient could be interpreted in two different ways. We can conclude that either the correlation between floods and life satisfaction is spurious or, alternatively, that the macro-economic variables are intervening variables and part of the causal effect of floods on life satisfaction operates through contemporary macroeconomic shocks. As flood disasters have been shown to negatively affect economic conditions (see Tavares 2004; Raschky 2007), both interpretations are plausible. Second, as region-specific effects cannot be controlled for in the cross-section analysis, we purge the data from nation specific effects and focus on the within-country variation. Table 14 depicts the results of the sensitivity analysis.

*Table 14*. Robustness check: Effect of flood hazards on life satisfaction controlling for macro-economic variables and country effects

| *Dependent Variable* | I | II | III | IV | V | VI | VII | VIII |
|---|---|---|---|---|---|---|---|---|
| Life satisfaction | All countries | Europe | United States | All countries | Europe | United States | All countries | Europe |
| *Flood* | | | | | | | | |
| Flood events | -0.037 ** | -0.038 ** | -0.014 | | | | | |
| | (-2.69) | (-2.67) | (-0.50) | | | | | |
| Flood distribution | | | | -0.020 * | -0.021 * | -0.003 (*) | 0.001 | 0.001 |
| | | | | (-2.49) | (-2.59) | (-1.96) | (0.19) | (0.24) |
| *Macro-economic variables* | | | | | | | | |
| GDP per capita growth | 0.139 (*) | 0.127 (*) | 0.723 ** | -0.021 | -0.020 | 0.715 ** | 0.218 * | 0.207 * |
| | (1.80) | (1.64) | (3.23) | (-0.11) | (-0.10) | (3.30) | (2.31) | (2.16) |
| Unemployment growth | -0.009 | -0.016 | -0.037 | -0.125 | -0.169 | 0.043 | 0.029 | 0.028 |
| | (-0.19) | (-0.27) | (-0.90) | (-1.10) | (-1.21) | (1.04) | (0.40) | (0.30) |
| *HH income* | | | | | | | | |
| ln(HH income) | 0.183 ** | 0.194 ** | 0.083 ** | 0.314 ** | 0.336 ** | 0.082 ** | 0.183 ** | 0.195 ** |
| | (50.86) | (48.63) | (12.13) | (14.63) | (14.94) | (11.49) | (25.05) | (22.86) |
| HH size$^{1/2}$ | -0.085 ** | -0.090 ** | -0.030 (*) | -0.224 ** | -0.237 ** | -0.030 * | -0.086 ** | -0.091 ** |
| | (-17.82) | (-17.85) | -1.78 | (-8.15) | (-8.17) | -2.01 | (-13.48) | (-13.17) |
| *Personal characteristics* | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| *Region specific effects* | Yes | Yes | Yes | No | No | No | No | No |
| *Country specific effects* | No | No | No | No | No | No | Yes | Yes |
| *Year specific effects* | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| *Constant* | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Number of observations | 315,317 | 302,321 | 12,996 | 315,317 | 302,321 | 12,996 | 315,317 | 302,321 |
| Number of clusters | 3,652 | 2,388 | 1,264 | 472 | 172 | 300 | 472 | 172 |
| Prob > F | n.a. | 0.000 | n.a. | 0.000 | 0.000 | 0.000 | n.a. | n.a. |
| $R^2$ | 0.188 | 0.189 | 0.121 | 0.103 | 0.105 | 0.098 | 0.180 | 0.182 |

*Notes*: (1) OLS estimates. (2) t-values are parentheses. (3) Standard errors are adjusted for clustering on level of regions and years (repeated cross-section) and on the level of regions (cross-section). (4) ** is significant at the 99% level, * at the 95% level, and (*) at the 90% level.

The coefficients for the flood variables are robust to the inclusion of the macro-economic variables. Hence, the partial correlation is neither spuriously caused by the simultaneity of economic decline and increased exposure to flood disasters, nor are economic growth shocks an important channel through which flood disasters affect life satisfaction. An exception is the estimate for the effect of flood disasters in the United States. The effects approximately halves, once business cycle effects are controlled for. If the growth rate of the GDP per capita at the county level is replaced by the disaster adjusted growth rate of GDP per capita at the state level, the coefficient remains robust (coefficient: -0.024; t-value: -0.88). Therefore, we tend to interpret the GDP per capita growth rate as an intervening variable. As can be seen from the columns VII and VIII of table 14, the negative effect of the variable capturing flood exposure is not robust to the inclusion of nation specific fixed-effects: If country dummies are included, the coefficient collapses. A possible explanation for this result could be that the effect is mainly identified by between country variation on the level of flood exposure, rather than by within country variation. In Europe, the average within country variance is 4.5, whereas the between country variance is 16.4. Another reason could be, of course, that individuals are fully compensated on housing markets for exposure of flooding (see the discussion in section 2.4.2). Therefore, in the remainder of the chapter, we focus on the flood event rather than the flood hazard distribution variable.

## 4.4 Implicit willingness-to-pay

As in chapter 3, section 3.5, we can now use the estimated coefficients for flood events and income to calculate the implicit *WTP* for a reduction of flood hazard. We calculate the implicit *WTP* for (i) the prevention of one sure flood disaster and (ii) a reduction of the probability of a flood disaster from 2.7% to 0%, i.e. a reduction of the risk of flooding by its mean. The estimates are based on the results for the whole sample presented in table 13, column 1 (and the corresponding ordered probit estimates). Table 15 depicts the results.

*Table 15*. *WTP* estimates for a reduction in the risk of flooding

| Average annual household income | | $19,475 |
|---|---|---|
| Compensating surplus | Absolute | In percent |
| Basis: least square estimations (table 13, column I) | | |
| Prevention of a sure event in region | $3,525 | 18.1% |
| | ($1,203) | (6.2%) |
| Decrease of annual flood probability by its mean of 0.027 | $105 | 0.5% |
| | ($39) | (0.2%) |
| Basis: ordered probit estimations | | |
| Prevention of a sure event in region | $3,363 | 17.3% |
| | ($1,178) | (6%) |
| Decrease of annual flood probability by its mean of 0.027 | $99 | 0.5% |
| | ($38) | (0.2%) |

*Notes*: (1) CS estimates are in 2004 U.S. dollars. (2) Standard errors estimated with the delta method are parentheses.

The average *WTP* for the prevention of one sure event in the region of residence is $3,525 or 18.1% of an average household income ($3,363 or 17.3% using the coefficients from the ordered probit estimates. For a reduction of the probability of flooding by its average, i.e. a reduction of the probability by 2.7%, an individual would be willing to pay $105 or about 0.5% of her annual household income ($99 or about 0.5% for the ordered probit estimates).

In order to assess the validity of our results, we compare our results to measures derived from hedonic market studies (convergent validity). Several case studies for U.S. cities estimate the price discount for houses located in 100-year floodplains, i.e. floodplains with an annual chance of flooding of at least 1%. These price discounts reflect the present value of expected future property damages and further losses caused by flood events. The price discounts can, therefore, be compared to an annual *CS* paid in perpetuity for a reduction in the probability of flooding by 1%. The *CS* is $38.85; the equivalent surplus would be only marginally higher, namely $38.93. Assuming an annual interest rate of a) 1%, b) 3% and c) 5%, the corresponding present values of the *CS* amount to a) $3,885, b) $1,295 and c) $777.

A comparison to the figures presented in table 16 reveals that the estimates based on the life satisfaction approach are lower than the one based on the hedonic market approach. There are at least three reasons for this discrepancy. First, the price discounts presented in table 16, are price discounts for properties located in a floodplain with an annual risk of flooding of at least

*Table 16*. Price discounts in hedonic market studies for houses located in 100-year floodplains in the United States

| Region and period | Δ Price | | Average house price | | Relative | Source |
|---|---|---|---|---|---|---|
| | Reported | In 2004 US$ | Reported | In 2004 US$ [a)] | Δ Price | |
| Oakland, NJ; 1970 | $0 | $0 | $30,269 | $147,259 [b)] | 0% | Zimmermann (1979) |
| Pequannock, NJ; 1970 | $0 | $0 | $28,302 | $137,689 [b)] | 0% | Zimmermann (1979) |
| Pompton Lakes, NJ; 1970 | $0 | $0 | $30,212 | $146,982 [b)] | 0% | Zimmermann (1979) |
| St. Louis, MO; 1969-1970 | $684 | $3,328 | $15,015 | $73,048 | 5% | Mark (1980) |
| Baton Rouge, LA; 1982-1984 | $4,800 | $8,295 | $75,000 | $129,612 [b)] | 6% | Shilling et al. (1985) |
| Monroe, LA; 1985 | $4,597 | $8,073 | $65,000 | $114,143 [d)] | 7% | MacDonald et al. (1987) |
| LaCrosse, WI; 1982-1984 | $6,049 | $11,001 | $50,178 | $91,259 [b)] | 12% | Donnelly (1989) |
| Monroe, LA; 1988 | $7,334 | $11,712 | $65,000 | $103,802 [d)] | 11% | MacDonald et al. (1990) |
| Fargo, ND, Moorhead, MN; 1995-1998 | $8,890 | $10,703 | $100,139 | $120,563 [b)] | 9% | Fridgen and Shultz (2004) |
| Alachua County, FL; 1980-1994[e)] | $1,034 | $2,371 | $73,115 | $167,619 [b)] | 1% | Harrison et al. (2001) |
| Alachua County, FL; 1994-1999[e)] | $2,893 | $6,633 | $73,115 | $167,619 [b)] | 4% | Harrison et al. (2001) |
| Pitt County, FL; 1992-1999[f)] | $4,888 | $5,133 | $129,816 | $136,322 [b)] | 4% | Bin and Polasky (2004) |
| Pitt County, FL; 1999-2002[f)] | $10,825 | $11,367 | $129,816 | $136,322 [b)] | 8% | Bin and Polasky (2004) |
| California; 1997-1998[g)] | $0 | $0 | $185,779 | $214,343 [c)] | 0% | Troy and Romm (2004) |
| California; 1998-1999[g)] | $7,998 | $9,228 | $193,453 | $223,197 [c)] | 4% | Troy and Romm (2004) |
| Average | | $5,856 | | $140,652 | 4% | |
| Average of positive estimates | | $7,986 | | $133,046 | 6% | |

*Notes*: [a)] Values are deflated with the CPI for all urban consumers provided by the Bureau of Labor Statistics. If a hedonic market study covers a period of more than one year, the average CPI value of the start and end of the period is chosen. If the study controls for time specific fixed effects or a time trend, the CPI value of the start month or year is chosen. [b)] Average price of house in sample; [c)] price of an house with average characteristics in the non-flood area; [d)] price of an average home; [e)] before/after NFI Reform Act of 1994; [f)] before/after Hurricane Floyd of 1999; [g)] before/after California Natural Hazard Disclosure Law (AB 1195).

1%. Several properties are located in floodplains with a much higher actual risk. Second, as discussed in sections 2.4.2, insured property damages are not captured by the life satisfaction approach using combined cross-section and time-series data. Third, higher average household income in the United States compared to most European countries may explain part of the discrepancy. Price discounts in European housing markets might well be lower. By the same token, the implicit *WTP* estimates for the United States based on the life satisfaction approach are higher than the estimates for the whole sample. The present value of the *CS* estimate based on the U.S. sample paid in perpetuity amounts to between $2,183 (with real interest rate of 5%) and $10,913 (with a real interest rate of 1%). However, other arguments would suggest the *CS* calculated with the life satisfaction approach to exceed the one calculated with the hedonic market approach. First, in absence of information disclosure on the risk of natural disasters, these risks are insufficiently reflected in property prices, as shown by Troy and Romm (2004). Second, the life satisfaction approach may also capture negative effects of floods that cannot be averted by buying a house outside the flood zone. An example of such effects are the detrimental consequences of floods for community life. Although the price discounts found in hedonic market studies for the United States are higher than our results for the 17 OECD countries, the fact that our estimate lies within the range of these price discounts strengthens confidence in the validity of our results.

## 4.5 Explorative analysis: Effects of risk transfer mechanisms

The effects of flood disasters on individual well-being also depend on the societal risk transfer mechanisms. The two most important risk transfer mechanisms in the area of natural hazards are catastrophe insurance and emergency relief or ad-hoc help. For numerous reasons, markets for natural hazard insurance either work imperfectly or do not exist at all (see Kunreuther 2001; Jaffee and Russell 2003). Therefore, various countries have implemented mandatory insurance systems in order to correct market imperfections. Insurance payouts and financial compensations reduce the burden after a disaster and should thus have a dampening effect on the impact of a flood disaster on life satisfaction.

In an exploratory analysis, we estimate to what extent mandatory insurance systems and emergency relief attenuate negative effects of flood disasters. This question is important for several reasons. First, the effects of flood events presented in table 13 are a weighted average of the

effects of flood events for which the affected population is (partly) compensated by risk transfer mechanisms and of flood events for which they are not. The following analysis allows us to recover the full uncompensated losses. Second, the magnitude of the attenuating effect reveals the relative importance of insurable property losses compared to non-insurable psychic costs. Third, we argue that the life satisfaction approach could be used to evaluate risk transfer mechanisms. Such mechanisms mitigate the adverse effect in case of a catastrophe, but impose an extra burden on all those who have to bear the costs. Both effects can, in principle, be measured in life satisfaction terms.

Unfortunately, a direct measure exists only for the existence of a mandatory insurance system. Two European countries in our sample, France and Spain, have a comprehensive mandatory insurance system. France made catastrophe insurance mandatory in 1981, in Spain it was mandatory for the whole period considered here (von Ungern-Sternberg 2004). In the United States, we count counties participating in the National Flood Insurance Program (NFIP) among the regions with mandatory insurance. In participating counties, insurance is available at a reduced premium to home-owners and mandatory for properties located in flood prone areas.

Data on emergency relief are not available. Therefore, we have to use proxy measures for this risk transfer mechanism. Emergency relief and ad-hoc help is operationalized by a dummy variable for countries and years with an election at the national level. Public choice theories suggest that incumbents have an incentive to provide generous emergency relief in election years to secure their re-election. For example, in the very close German election race in 2002, the German chancellor Gerhard Schroeder managed to pull ahead his opponent by his decisive handling of the disastrous summer floods in eastern Germany and by granting large financial assistance to the flood victims (Schwarze, R. and Wagner 2004). Systematic evidence on the influence of elections is provided by Garrett and Sobel (2003) in their analysis of the determinants of the generosity of disaster relief by the FEMA in the United States. Table 17 presents the estimated coefficients for flood events in regions without risk transfer mechanisms, for the direct effects of the risk transfer mechanisms and for the interaction terms of flood events and the risk transfer mechanisms for the whole sample and for the sub-samples.

*Table 17*. Interaction effects: Effects of flood hazards on life satisfaction under different risk transfer mechanisms

| *Dependent Variable* | I | | II | | III | | IV | | V | | VI | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Life satisfaction | All countries | | Europe | | United States | | All countries | | Europe | | United States | |
| | Coef. | t-value | Coef. | t-value | Coef. | t-value | Coef. | t-value | Coef. | t-value | Coef. | t-value |
| *Flood hazards* | | | | | | | | | | | | |
| Flood events | -0.044 ** | -2.75 | -0.043 ** | -2.66 | -0.064 (*) | -1.84 | -0.048 * | -2.49 | -0.048 * | -2.45 | -0.079 | -0.56 |
| *Risk Transfer Mechanisms* | | | | | | | | | | | | |
| Mandatory insurance | 0.019 | 1.29 | 0.018 | 1.23 | 0.087 | 1.52 | | | | | | |
| Election year | | | | | | | 0.006 | 1.23 | 0.006 | 1.23 | n.a. | |
| *Interaction terms* | | | | | | | | | | | | |
| Flood · mandatory insurance | 0.039 | 1.43 | 0.036 | 1.20 | 0.070 | 1.40 | | | | | | |
| Flood · election year | | | | | | | 0.030 | 1.28 | 0.029 | 1.18 | 0.057 | 0.40 |
| *HH income* | | | | | | | | | | | | |
| ln(HH income) | 0.180 ** | 50.58 | 0.189 ** | 48.34 | 0.084 ** | 12.22 | 0.180 ** | 50.61 | 0.189 ** | 48.35 | 0.084 ** | 12.28 |
| HH size$^{1/2}$ | -0.082 ** | -17.64 | -0.086 ** | -17.60 | -0.032 (*) | -1.88 | -0.086 ** | -17.56 | -0.086 ** | -17.56 | -0.032 (*) | -1.89 |
| *Personal characteristics* | Yes | | Yes | | Yes | | Yes | | Yes | | Yes | |
| *Region specific effects* | Yes | | Yes | | Yes | | Yes | | Yes | | Yes | |
| *Year specific effects* | Yes | | Yes | | Yes | | Yes | | Yes | | Yes | |
| *Constant* | Yes | | Yes | | Yes | | Yes | | Yes | | Yes | |
| Number of observations | 341,748 | | 328,610 | | 13,138 | | 341,748 | | 328,610 | | 13,138 | |
| Number of clusters | 3,854 | | 2,569 | | 1,285 | | 3,854 | | 2,569 | | 1,285 | |
| Prob > F | n.a. | | 0.000 | | n.a. | | n.a. | | 0.000 | | n.a. | |
| $R^2$ | 0.186 | | 0.186 | | 0.121 | | 0.186 | | 0.186 | | 0.121 | |
| *Marginal effect of flood disasters* | M.E. | St. Err. | M.E. | St. Err. | M.E. | St. Err. | M.E. | St. Err. | M.E. | St. Err. | M.E. | St. Err. |
| With risk transfer mechanisms | -0.005 | 0.022 | -0.007 | 0.025 | 0.006 | 0.037 | -0.018 | 0.014 | -0.019 | 0.016 | -0.022 | 0.028 |
| Without | -0.044 ** | 0.016 | -0.043 ** | 0.016 | -0.064 (*) | 0.035 | -0.048 ** | 0.019 | -0.048 ** | 0.019 | -0.079 | 0.141 |

*Notes*: (1) OLS estimates. (2) Standard errors are adjusted for clustering on level of regions and years (repeated cross-section) and of regions level (cross-section). (3) ** is significant at the 99% level, * at the 95% level, and (*) at the 90% level.

We desist from interpreting the direct effects of risk transfer mechanisms. The direct effect for mandatory insurance is difficult to interpret because in Europe only France changed the regime. In the United States, 16% of the counties in our sample changed their NFIP participation status. The positive effect of participation in the NFIP might either be due to federal transfers or omitted variables. Obviously, election years are different from other years in other respects than the provision of emergency relief. For the effect of risk transfer mechanisms, we find neither statistically significant mitigating effects nor can we reject at conventional levels of significance the hypothesis that the effect of flood disasters in regions with risk transfer mechanisms is zero. Therefore, the results have to be interpreted tentatively. Nevertheless, they are illuminating. The effects of floods on life satisfaction in regions without risk transfer-mechanisms are persistently larger (in absolute terms) than the effect of floods in all regions. Risk transfer mechanisms have large attenuating effects. For example, mandatory insurance comes close to fully compensating the effect of a flood event. Consequently, the effects of flood events in regions with risk transfer mechanisms are small. As column I in table 17 shows, flood disasters lower life satisfaction by 0.044 points in regions without mandatory insurance, 122% of the overall effect reported in column I of table 13. In contrast, flood disasters that hit regions with mandatory flood insurance, decrease reported life satisfaction only by 0.005 points or by 11% compared to regions without mandatory insurance. The result for the European sub-sample is very similar (see column II of table 17). In the American sub-sample the compensation by the NFIP even seems to slightly overcompensate the negative effect of flood disasters (column III of table 17). As mandatory flood insurance, relief provided in election years mitigates the adverse effects of flood disasters. In the whole sample (column IV of table 17) flood disasters occurring in non-election years lower life satisfaction by 0.048 points (133% of the overall effect), flood disasters occurring in election years by 0.018 points (35% the effect in non-election years). Again, the results for the European sub-sample are very similar (column V of table 17). The results for the United States are even more pronounced (column VI of table 17). In the United States, flood disasters in non-election years lower life satisfaction by 0.080 points (313% of the overall effect), while flood disasters in election years lower life satisfaction by only 0.023 points (28% the effect in non-election years). These results suggest that non-insurable psychic costs are small compared to property damages. According to our point estimates for mandatory flood insurance, they are at most 11%. This corresponds to the results of MacDonald, Murdoch and White (1987) and MacDonald et al.

(1990) who compare flood insurance premiums to price discounts found in housing markets for houses located in floodplains. Further, one can use the effects of flood disasters corrected for compensations individuals might have received from risk transfer mechanisms to calculate *CS*s. For a hypothetical reduction in the probability of flooding from 0.01 to 0, individuals in countries and years without a system of mandatory flood insurance would be willing to pay \$47. The (purged) *CS* for a reduction in the probability of flooding by 0.01 paid in perpetuity lies between \$946 (using an annual interest rate of 5%) and \$4,729 (using an annual interest rate of 1%). Compared to the price discounts in the hedonic market studies reported in table 16, the (purged) *CS* is still below the average price discount, but the difference is smaller.

## 5. Application to terrorism

### 5.1 Introduction

Most people take it for granted that terrorism is the major plague we are now dealing with in the 21st century. On a number of occasions, terrorists succeeded in inflicting massive civilian casualties and colossal damage, as in the case of the attacks on the World Trade Towers in New York on September 11, 2001, the bombings aboard four commuter trains in Madrid on March 11, 2004, and the bombings on the London subway on July 7, 2005. Moreover, because of a radicalization of Muslim minorities in many European countries, the threat of terrorism is growing (e.g. Economist 2007c). However, although in connection with the proliferation of religious terrorism the propensity for spectacular large-scale attacks increased, terrorism is not restricted to Islamic militants in general and al-Qaeda in particular. Rather, many countries were plagued by terrorist campaigns in the twentieth century. Fighters in anticolonial struggles, ethnic separatist groups, revolutionary left-wing terrorists and their right-wing counterparts all tried to harm their opponents in order to force them to yield to their demands or overthrow them (see e.g. Hoffman, B. 1998; Wilkinson 2000).

Two avenues have been pursued in the literature to assess the ramifications and consequences of terrorism. First, social scientists generally determine the human costs of terrorism by directly counting the victims of terrorist activity (e.g. Fay, Morrissey and Smyth 1999). Second, economic scholars usually analyze the effects terrorist acts have on various aspects of the economy (for a review see Frey, Luechinger and Stutzer 2007). However, both avenues ignore important costs of terrorism. Body counts are inept at grasping repercussion of terrorist activities beyond the immediate victims and their dependants such as the fear and terror instilled by acts of terrorism. Economic consequences exclude, by definition, all non-market values and the grief of the victims and the bereaved are disregarded as well as fear and terror. In this chapter, we use the life satisfaction approach to estimate the consequences for the individuals affected by terrorist activities in France, the Republic of Ireland and the United Kingdom. France is the Western European country with the highest number of recorded international terrorist incidents in the last quarter of the twentieth century. Similarly, the Northern Ireland conflict, beyond doubt one of the most violent conflicts in Europe's recent history, affected not only Northern Ireland but also Great Britain and the Republic of Ireland.

## 5.2 Terrorism: Data and pattern

In order to capture the intensity of the terrorist activity in different regions and years, we use two different terrorism indicators: the number of reported terrorist attacks and the number of fatalities. For both France and the British Isles, the number of attacks and the number of fatalities refer to one of three regions in a particular year (see section 2.4.3). In the case of France, the regions are Ile-de-France (including Paris), Provence-Alpes-Côte d'Azur (including Corsica) and the rest of France. In the case of the British Isles, the regions are the Republic of Ireland, Northern Ireland and Great Britain.

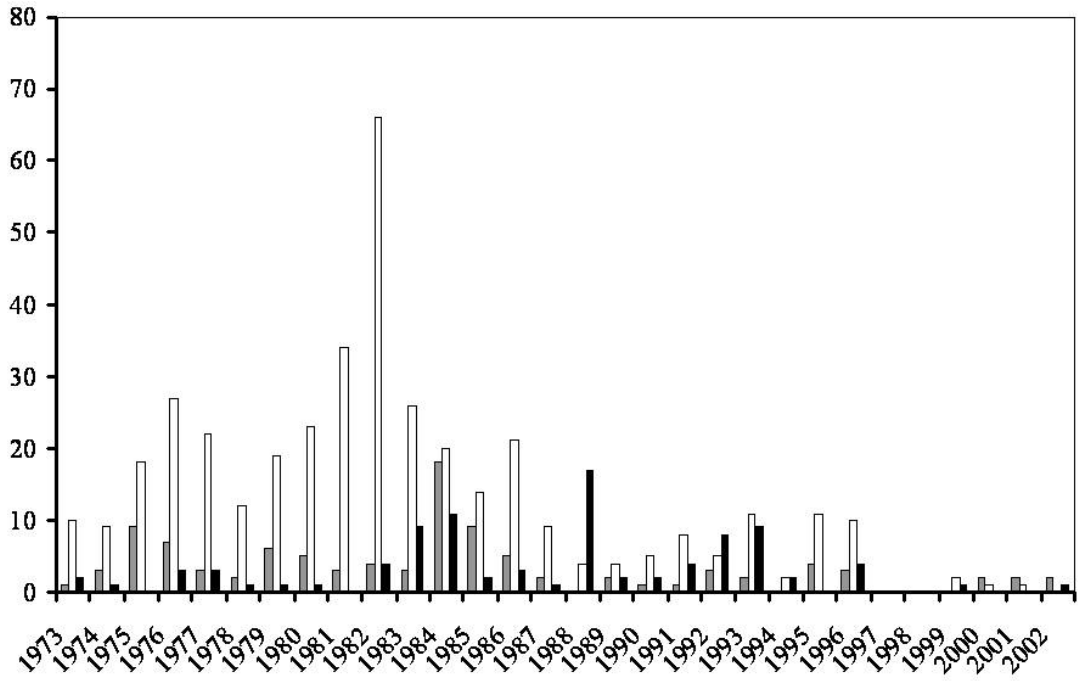
The first indicator of terrorism, the number of terrorist attacks, is constructed on the basis of the *RAND-St. Andrews Chronology of International Terrorism* (see e.g. Hoffman, B. and Hoffman 1995; made publicly available by the Oklahoma City National Memorial Institute for the Prevention of Terrorism on its homepage (www.mipt.org)), the *TWEED – Terrorism in Western Europe: Event Data*-project (see Engene 2007) and statistics on the *Security Related Incidents* in Northern Ireland provided by the Police Service of Northern Ireland (PSNI; www.psni.police.uk). The fatalities variable is constructed on the basis of the RAND-data and a comprehensive list of deaths resulting from the conflict in Northern Ireland; the list has been compiled by Sutton (1994) and updated by the Conflict Archive on the Internet (www.cain.ulst.ac.uk).

In the case of France, both the incident variable and the fatalities variable are entirely constructed on the basis of the RAND-data. Every reported incident contains a short description with – in the majority of cases – the exact location of the incident. This allows us to assign the incidents (and fatalities) to a particular region (only 16 incidents cannot be attributed to a region in the case of the United Kingdom and 11 in the case of France). The RAND-data are restricted to international terrorism. However, international terrorism is broadly defined and includes attacks by Corsican and Northern Irish separatist groups in France and Great Britain, as well as attacks by domestic terrorist groups whenever foreigners are involved. In France, for example, several attacks are recorded for which the *Action Directe* (AD) claimed credit, especially in the mid 1980s when the AD tried to ally themselves with the German *Rote Armee Fraktion* (RAF). In the same category fall also some rather bizarre attacks such as attacks on international computer firms by the *Comité Liquidant ou Détournant les Ordinateurs* (Com-

mittee for Liquidation of Computers, CLODO) or the bombing of gas pipelines by the *Comité d'Action Viticole* (Action Committee of Winegrowers, CAV). But also many state-sponsored terrorist activities took place on French territory. An example is the murder of the former Iranian Prime Minister Shapour Bakhtiar in Paris in 1991 by a hit-squad which, according to the French investigating judge, was carried out under the direct orders of the Iranian regime (Wilkinson 2000, p. 66). Furthermore, France was plagued with the spillover of Basque terrorism into France, the spillover of activities by the *Groupe Islamic Armée* (GIA) and other incidents related to the Middle East. Although international terrorism plays an important role in France and although international terrorism is broadly defined, the RAND-data do not reflect the terror situation in France to the whole extent. For the years in our sample, the TWEED-data, focusing on domestic terrorism, record 2,463 incidents; the RAND-data, in contrasts, record only 506 incidents. Because the TWEED-data contain no information on the geographical location of an incident, in the case of France, the RAND-data cannot be supplemented with the TWEED-data. For France, the following analysis rests on the assumption that either it is mainly the international terrorist attacks that have negative effects on life satisfaction (probably because they are more severe) or that international terrorist attacks reflect the pattern and evolution of terrorism more generally. The former conjecture is supported by the fact that international attacks are indeed more often fatal than domestic attacks. Although the RAND-data contain fewer incidents compared to the TWEED-data, more fatalities are recorded (147 in the RAND-data compared to 111 in the TWEED-data). The latter conjecture is supported by a relatively high correlation between the RAND-data and the TWEED-data. The correlation coefficient for the number of incidents is 0.67, the correlation coefficient for the number of fatalities is 0.80. Figures 6 and 7 depict the annual number of attacks and the annual number of fatalities, respectively, for Paris, the region Provence-Alpes-Côte d'Azur and the rest of France separately.

In Paris and the rest of France, the number of attacks is decreasing over the whole period; in the region Provence-Alpes-Côte d'Azur the number of attacks peaks in the second half of the 1980s. Compared to the other regions, Paris experienced around the fourfold number of terrorist attacks.

***Figure 6*. Number of terrorist attacks in France, 1973-2002**

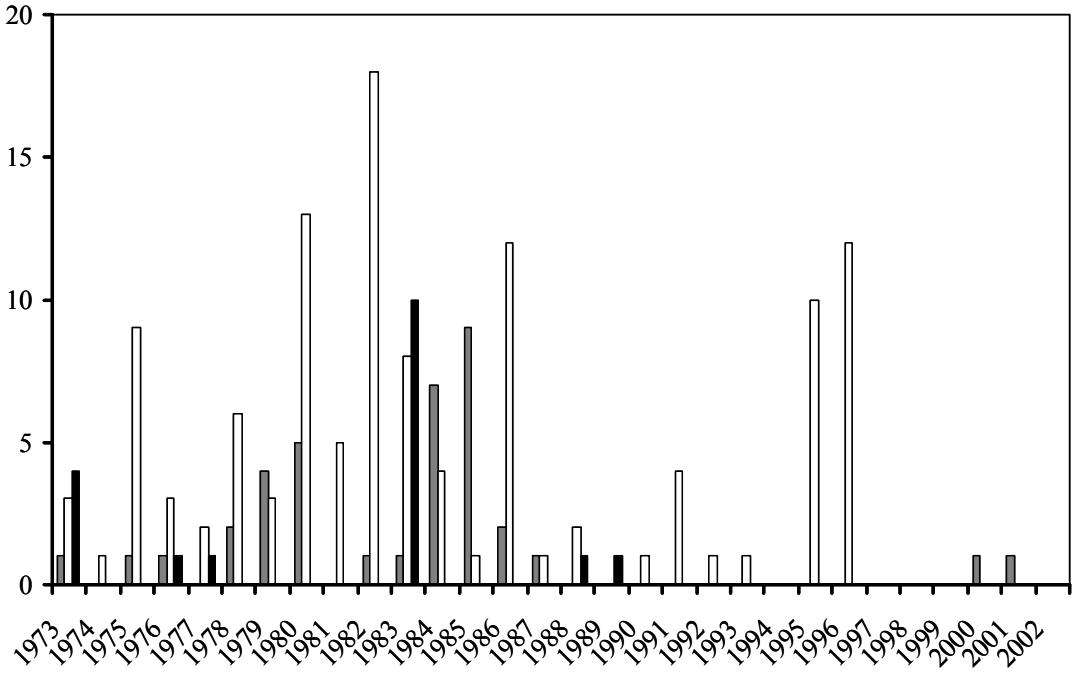



| | Rest of France | Paris | Provence-Alpes-Côte d'Azur |
|---|---|---|---|
| Mean | 3.46 | 13.04 | 3.35 |
| Std. Dev. | 3.94 | 13.80 | 4.15 |
| Min | 0 | 0 | 0 |
| Max | 18 | 66 | 17 |

***Source:*** **RAND-St. Andrews Chronology of International Terrorism, provided by MIPT (www.mipt.org).**

The number of fatalities is decreasing in all three regions of France, in the rest of France especially since the mid-1980s; again, most deaths occurred in Paris.

*Figure 7*. Number of fatalities in France, 1973-2002



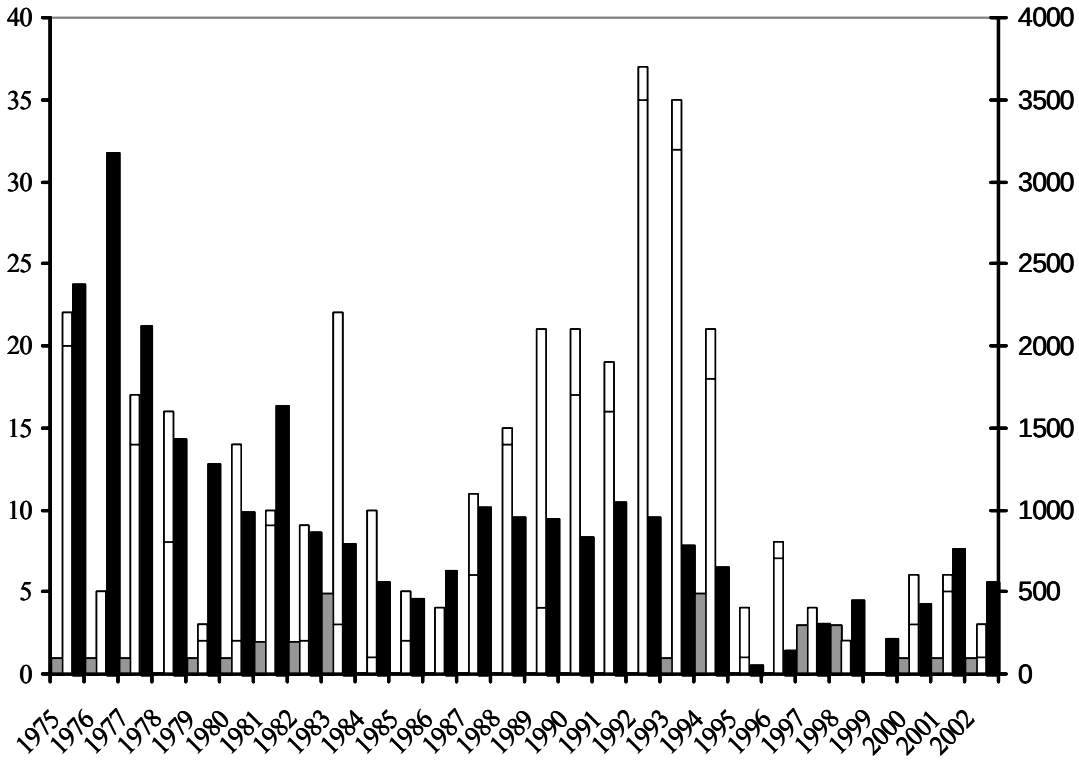

| | Rest of France | Paris | Provence-Alpes-Côte d'Azur |
|---|---|---|---|
| Mean | 1.42 | 3.58 | 0.70 |
| Std. Dev. | 2.32 | 4.73 | 2.07 |
| Min | 0 | 0 | 0 |
| Max | 9 | 18 | 10 |

*Source:* RAND-St. Andrews Chronology of International Terrorism, provided by MIPT (www.mipt.org).

The RAND-data are also an important building block in constructing the terrorism variables for the United Kingdom and the Republic of Ireland. A large fraction of reported incidents in Great Britain are related to the Northern Ireland conflict, the "Troubles", and were committed by the *Provisional Irish Republican Army* (PIRA) and to a lesser extent by the *Irish National Liberation Army* (INLA). In 1972, the PIRA moved their bombing campaign to Great Britain. The first of many sporadic, but mostly spectacular, PIRA attacks was a bomb planted at Al-

dershot military barracks killing seven and wounding five, two of whom subsequently died. A comparison of the RAND-data to the comprehensive list of fatalities compiled by Sutton (1994) shows that most attacks related to the Troubles that have been perpetrated in Great Britain are recorded in the RAND-data: 87% of the persons killed in Great Britain and recorded on Sutton's (1994) list can also be found in the RAND-data. Moreover, the fraction of 87% even underestimates the congruence for fatal attacks because, in contrast to the RAND-data, Sutton's (1994) list also contains terrorists who died in premature bomb explosions, political activists that died in hunger strikes and people who died in the aftermath of an attack. As an example, the RAND-data record a bomb attack on March 27th, 1976, in a crowded exhibition hall in London that injured over 80 persons but killed no one, at least not immediately; Sutton's (1994) list, on the other hand, contains a woman who died on April 17th, 1976, three weeks after being injured in a bomb attack on an exhibition hall in London. Without question, both observations relate to the same event. Thus, the RAND-data adequately capture Northern Irish terrorism in Great Britain. The same seems to be the case for the low-scale campaign of Welsh separatist groups such as the *Meibion Glyndwr*. While we are confident about the completeness of the RAND-data for Great Britain, the RAND-data are clearly deficient for Northern Ireland and the Republic of Ireland. Only 3% of the persons on Sutton's (1994) list killed in Northern Ireland and only 13% of the persons on Sutton's (1994) list killed in the Republic of Ireland are recorded in the RAND-data. Therefore, for the Republic of Ireland, we supplement the RAND-data with the TWEED-data. The TWEED-data record a good deal of Northern Ireland-related acts perpetrated in the Republic. In order to avoid double-counting of acts, we exclude all acts that are already recorded in the RAND-data by comparing information on the date, perpetrator, target etc. of the acts in the two datasets. The two datasets thus combined contain 26% of the persons in Sutton's (1994) list. Again, the 26% underestimate the true congruence for fatal attacks because a large fraction of persons on Sutton's (1994) list are victims of feuds between paramilitary groups, neutralized informers, abductees, or persons shot in armed robberies. For Northern Ireland itself, we use statistics on the number of incidents provided by the PSNI. Because the RAND-data are essentially useless for Northern Ireland and because the PSNI-data contain only the annual number of incidents without further information on individual incidents, we completely replace the RAND-data by the PSNI-data for Northern Ireland. Figure 8 depicts the annual number of terrorist attacks for the Republic of Ireland, Great Britain and Northern Ireland.

*Figure 8*. Number of terrorist attacks in the U.K. and Ireland, 1975-2002




| | | | |
|---|---|---|---|
| Mean | 1.08 | 13.12 | 1,035.88 |
| Std. Dev. | 1.47 | 9.97 | 709.57 |
| Min | 0 | 0 | 232 |
| Max | 5 | 37 | 3,336 |

*Notes:* For Great Britain, the bars above partition denote attacks not related to the 'Troubles'.
*Source:* RAND-St. Andrews Chronology of International Terrorism, provided by MIPT (www.mipt.org), Sutton (1994) and an updated version of the Sutton index provided by CAIN Web Service (www.cain.ulst.ac.uk), and statistics provided by the PSNI (www.psni.police.uk).

In the Republic of Ireland, no clear pattern is visible. In Great Britain, the number of attacks peaks in the second half of the 1980s and early 1990s. Measured in the number of attacks, the climax of violence in Northern Ireland was up to 1976 (or, alternatively, 1977). By far the most attacks were perpetrated in Northern Ireland; the number of attacks is around 960 times higher compared to Ireland and around 80 times higher compared to Great Britain. In Figure 8,

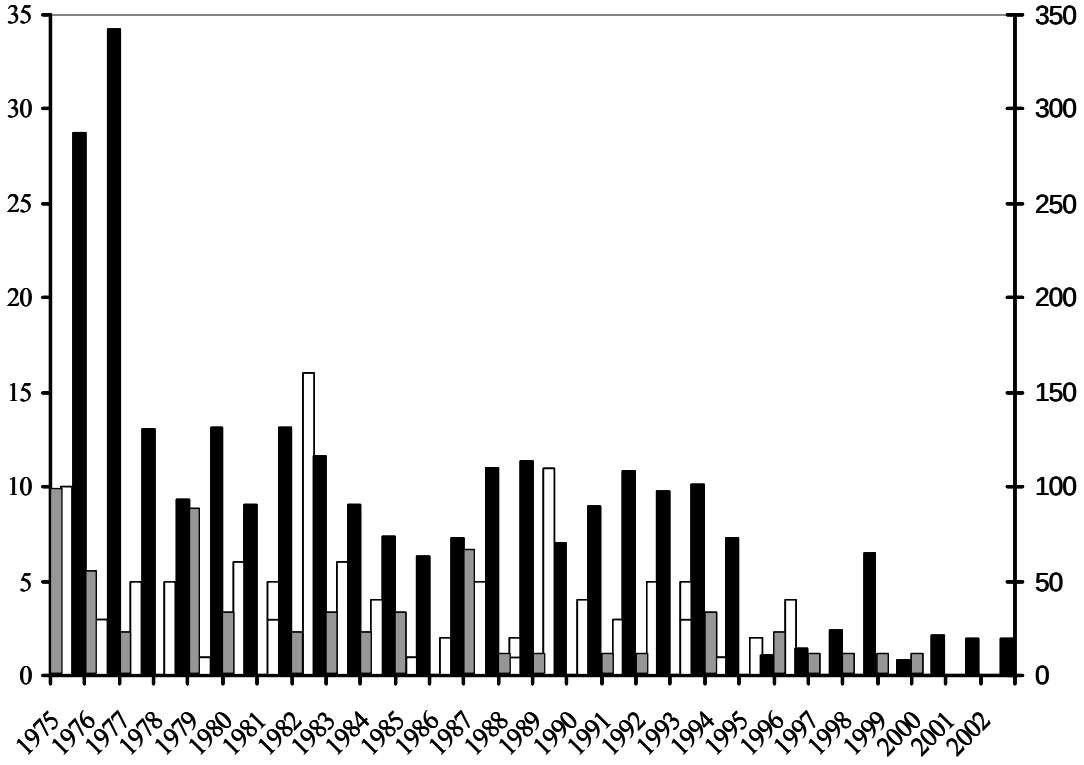
the part of the bars for Great Britain above the partitions represents the number of attacks that are not related to the Northern Ireland conflict.

For the Republic of Ireland and the United Kingdom, the variable on the number of fatalities is constructed on the basis of the RAND-data and Sutton's (1994) list. The latter is not restricted to terrorism in particular, but includes political violence in general. Though the PIRA was always the highest taker of life, killing civilians, security forces and prison staff, the UDA and UVF were also very active; the interaction between these groups is generally referred to as sectarian 'tit-for-tat' exchanges (McKittrick and McVea 2001, p. 109-110). Feuds, such as the ones between the *Provisional* and *Official* IRA in 1975 and between the UDA and UVF in 2000, as well as hunger strikes on the part of imprisoned IRA members in 1981, added to the death toll. On the other hand, a considerable number died at the hand of security forces. British paratroopers killed 14 demonstrators on the Bloody Sunday of 1972, British intelligence played a part in the Dublin and Monaghan bombing in 1974, and the army's undercover SAS regiment staged ambushes in which IRA members – and innocent bystanders – were shot, to name but a few examples. Sutton's (1994) list is one of the most comprehensive published records on the deaths in the Troubles; it excludes only deaths indirectly due to the Troubles such as those caused by army vehicles and heart attacks (see Fay, Morrissey and Smyth 1999, pp. 125-132, for a comparison of different lists). In combining the RAND-data and Sutton's (1994) list, we use again the detailed information on the attacks in order to avoid double-counting of attacks. Deaths from attacks not related to the Northern Ireland conflict are limited to Great Britain (part of the bars for Great Britain in Figure 9 above partition) and occur neither in the Republic of Ireland nor Northern Ireland. The deaths are in large part related to spillover terrorism from the Middle East. The annual number of fatalities for the Republic of Ireland, Great Britain and Northern Ireland is shown in Figure 9.

In the Republic of Ireland, the number of fatalities is decreasing; in Great Britain, no clear trend is visible, except for a small peak in the second half of the 1980s. Even more pronounced than with the number of attacks, the number of fatalities in Northern Ireland plummeted in 1977. Nevertheless, the number of fatalities remained high for the whole period under consideration. This corresponds to the observations of McKittrick and McVea (2001, p.

133) that 1977 "was a true turning-point in that violence fell dramatically, and would never again rise to the scale experienced in the 1971-76 period." As with the number of attacks, Northern Ireland has the largest death toll, with between around 20 and 75 times the number of fatalities compared to Great Britain and the Republic of Ireland, respectively.

*Figure 9*. Number of fatalities in the U.K. and Ireland, 1975-2002




| | | | |
|---|---|---|---|
| Mean | 1.08 | 3.8 | 80.84 |
| Std. Dev. | 2.16 | 3.95 | 62.99 |
| Min | 0 | 0 | 7 |
| Max | 9 | 16 | 287 |

*Notes:* For Great Britain, the bars above partition denote attacks not related to the 'Troubles'.
*Source:* RAND-St. Andrews Chronology of International Terrorism, provided by MIPT (www.mipt.org), Sutton (1994) and an updated version of the Sutton index provided by CAIN Web Service (www.cain.ulst.ac.uk), and statistics provided by the PSNI (www.psni.police.uk).

## 5.3 Effects on life satisfaction

### 5.3.1 Data and empirical strategy

As in chapter 4, the EB is our data source for the individual-level data with information on people's life satisfaction and household income. The sample period runs from 1973 to 2002. Observations from south-east France in 1987 and 1990 are excluded because they cannot be properly assigned to the different regions. Similarly, observations from the year 1973 are not included in the estimations for the British Isles because the Northern Irish sub-sample is included in the sample of Great Britain. As in chapter 4, respondents below age 15 are excluded. The sample of the baseline regressions contains a total of 100,382 observations for which a complete set of data for the main variables is available. The number of observations is 30,244 for Great Britain, 7,891 for Northern Ireland, 24,185 for the Republic of Ireland, and 38,062 for France.

We use the same life satisfaction and income variables as in the European sample of chapter 4. We also use a nearly identical set of personal characteristics as control variables. Minor deviations in the set of control variables between the two chapters can be explained by the fact that we had to combine two different datasets in chapter 4. Based on the data set described, we estimate micro-econometric happiness functions of the following form:

$$LS_{irt} = \beta_0 + \beta_1 T_{rt} + \beta_2 \ln(m_{irt}) + \beta_3 Z_{irt} + \rho_r + \tau_t + \varepsilon_{irt}, \tag{13}$$

where, as usual, $LS_{irt}$ is the life satisfaction of an individual $i$ living in region $r$ at time $t$, $T_{rt}$, the level of terrorist activity, $m_{irt}$ the individual's household income, $Z_{irt}$ other personal characteristics and $\rho_r$ and $\tau_t$ region and time fixed effects, respectively. Analogous to previous chapters, we use a robust estimator of variance, because random disturbances are potentially correlated within groups or clusters, here cross-sectional units for a specific year. We estimate equation 13 by least squares and ordered probit regressions but report intermediate results only for the former.

### 5.3.2 Basic results

As can be seen from table 18, terrorism negatively affects people's self-reported life satisfaction in a sizeable and statistically significant way. An increase in one standard deviation in the

*Table 18*. Basic results: Effect of terrorism on life satisfaction, U.K., Ireland and France, 1973-2002

| | U.K. and Ireland | | | | | | France | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Dependent Variable* | I | | | II | | | III | | | IV | | |
| Life satisfaction | Coef. | | t-value | Coef. | | t-value | Coef. | | t-value | Coef. | | t-value |
| *Terrorism* | | | | | | | | | | | | |
| Incidents | -7.6E-5 | ** | -3.90 | | | | -2.2E-3 | ** | -2.74 | | | |
| Fatalities | | | | -6.4E-4 | ** | -3.45 | | | | -5.0E-3 | * | -2.50 |
| *HH income* | | | | | | | | | | | | |
| ln(HH income) | 0.168 | ** | 19.12 | 0.167 | ** | 19.03 | 0.250 | ** | 20.29 | 0.250 | ** | 20.23 |
| HH size$^{1/2}$ | -0.095 | ** | -7.84 | -0.094 | ** | -7.77 | -0.160 | ** | -12.13 | -0.160 | ** | -12.09 |
| *Personal characteristics* | | | | | | | | | | | | |
| Male | Reference group | | | Reference group | | | Reference group | | | Reference group | | |
| Female | 0.081 | ** | 11.82 | 0.081 | ** | 11.80 | 0.033 | ** | 3.85 | 0.033 | ** | 3.87 |
| Age | -0.016 | ** | -12.24 | -0.016 | ** | -12.32 | -0.022 | ** | -12.33 | -0.022 | ** | -12.33 |
| Age$^2$ | 2.E-4 | ** | 14.41 | 2.E-4 | ** | 14.48 | 2.E-4 | ** | 12.04 | 2.E-4 | ** | 12.05 |
| Single | Reference group | | | Reference group | | | Reference group | | | Reference group | | |
| Married | 0.079 | ** | 6.29 | 0.079 | ** | 6.31 | 0.057 | ** | 4.10 | 0.057 | ** | 4.09 |
| Living together | 0.002 | | 0.09 | 0.001 | | 0.07 | 0.022 | | 1.44 | 0.022 | | 1.44 |
| Separated | -0.277 | ** | -9.45 | -0.277 | ** | -9.42 | -0.179 | ** | -4.99 | -0.179 | ** | -5.00 |
| Divorced | -0.209 | ** | -8.99 | -0.209 | ** | -8.98 | -0.146 | ** | -6.20 | -0.147 | ** | -6.22 |
| Widowed | -0.099 | ** | -5.89 | -0.099 | ** | -5.91 | -0.105 | ** | -4.76 | -0.106 | ** | -4.78 |
| No children in HH | Reference group | | | Reference group | | | Reference group | | | Reference group | | |
| One child | -0.025 | (*) | -1.74 | -0.025 | (*) | -1.73 | 0.012 | | 0.64 | 0.012 | | 0.62 |
| Two children | -0.016 | | -0.96 | -0.016 | | -0.97 | 0.061 | * | 2.56 | 0.060 | * | 2.53 |
| Three children | -0.023 | | -0.87 | -0.023 | | -0.88 | 0.076 | * | 2.58 | 0.075 | * | 2.56 |
| Four and more children | -0.025 | | -0.94 | -0.025 | | -0.96 | -0.081 | | -1.21 | -0.082 | | -1.22 |

*To be continued.*

*Table 18*, part 2

| | U.K. and Ireland | | | | | | France | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | I | | | II | | | III | | | IV | | |
| | Coef. | | t-value | Coef. | | t-value | Coef. | | t-value | Coef. | | t-value |
| Employed or self-employed | Reference group | | | Reference group | | | Reference group | | | Reference group | | |
| Other occupation | 0.130 | ** | 6.85 | 0.130 | ** | 6.84 | 0.239 | ** | 9.81 | 0.239 | ** | 9.82 |
| Housekeeping | -0.038 | ** | -3.55 | -0.038 | ** | -3.55 | 0.061 | ** | 4.79 | 0.061 | ** | 4.78 |
| Retired | -0.002 | | -0.16 | -0.002 | | -0.15 | 0.152 | ** | 7.17 | 0.152 | ** | 7.16 |
| Unemployed | -0.411 | ** | -18.83 | -0.410 | ** | -18.80 | -0.202 | ** | -8.35 | -0.202 | ** | -8.35 |
| Living in rural area | Reference group | | | Reference group | | | Reference group | | | Reference group | | |
| Living in small towns | -0.051 | ** | -5.27 | -0.051 | ** | -5.26 | -0.065 | ** | -5.66 | -0.066 | ** | -5.68 |
| Living in a big town | -0.120 | ** | -11.90 | -0.120 | ** | -11.91 | -0.078 | ** | -6.03 | -0.078 | ** | -6.10 |
| *Region specific effects* | Yes | | | Yes | | | Yes | | | Yes | | |
| *Year specific effects* | Yes | | | Yes | | | Yes | | | Yes | | |
| *Constant* | Yes | | | Yes | | | Yes | | | Yes | | |
| Number of observations | 62,320 | | | 62,320 | | | 38,062 | | | 38,062 | | |
| Number of clusters | 75 | | | 75 | | | 76 | | | 76 | | |
| Prob > F | 0.000 | | | 0.000 | | | 0.000 | | | 0.000 | | |
| $R^2$ | 0.079 | | | 0.079 | | | 0.074 | | | 0.074 | | |

*Notes*: (1) OLS estimates. (2) Standard errors are adjusted for clustering within regions per year. (3) ** is significant at the 99% level, * at the 95% level, and (*) at the 90% level.

number of recorded incidents, i.e. an increase of 154.03 incidents in the United Kingdom and Ireland and an increase of 5.59 incidents in France, lowers life satisfaction by 0.012 and 0.013 points, respectively, on the 4-point scale. An increase in one standard deviation in the number of recorded fatalities, an increase in the number of fatalities by 14.42 in the United Kingdom and Ireland and by 1.78 in France, lowers life satisfaction by 0.009 points in both countries. These are large effects, indicating that a reduction of the terrorist threat by one standard deviation is equivalent to between 0.9 and 1.3 percent of the population of France and the British Isles moving from, for example, not very satisfied [2] to fairly satisfied [3] with the life they lead. Household income has, again, a positive effect on life satisfaction that is highly statistically significant. The partial correlations between log of income and life satisfaction are comparable to the estimates for the European sample (e.g. table 13); it is 0.168 for the United Kingdom and Ireland and around 0.250 for France. Thus, when income is doubled, on average, a 0.116 points higher life satisfaction is reported in the United Kingdom and Ireland, and a 0.173 points higher life satisfaction in France.

For the estimates in table 18, the cross-section variance is based on three regions per country (see sections 2.4.3 and 5.2). However, the EB-data allow identification based on a higher resolution of the life satisfaction and terrorism data. For the British Isles, 13 regions can be differentiated: the Republic of Ireland, Northern Ireland, Scotland, Wales, the eight Standard Statistical Regions of England and Greater London. For France the data can be disaggregated on the level of the 21 régions of continental France (incl. Corsica). Based on this higher resolution data, the coefficient for the number of incidents decreases by 1.4% to -7.5E-5 (t-value: -3.90) in the case of the United Kingdom and Ireland and by 19.7% to -1.8E-3 (t-value: -2.74) in the case of France; the coefficient for the number of fatalities decreases by 1.3% to -6.3E-4 (t-value: -3.89) in the case of United Kingdom and Ireland and by 25.4% to -3.7E-3 (t-value: -1,83) in the case of France.[31] Thus, highly disaggregated data persistently yield smaller estimates. This is consistent with the notion that terrorism has important spillovers across regional boundaries.

[31] Note that it is not possible to directly compare the t-values. Because robust standard errors are adjusted for clustering on region and year level, we have fewer degrees of freedom in the estimates based on the supra-regional level.

### 5.3.3 Robustness tests and extensions

We modify the baseline regressions in three respects. On the one hand, these modifications allow us to check the validity and plausibility of the results. On the other hand, the modifications provide further insights regarding the effect of terrorism on life satisfaction. First, we analyze the sensitivity of the estimates to the exclusion of individual region-year combinations. Second, we include variables capturing the economic situation, more precisely the growth rate of GDP per capita and the unemployment rate, in order to address issues of simultaneity. Including these macro-economic variables also allows us to determine whether terrorism affects life satisfaction through simultaneous effects on the economy. Third, as a further test to rule out a spurious effect of terrorism on life satisfaction, we interact terrorism with dummy variables for sub-groups of the population that are expected to suffer disproportionately from terrorism. In this way, the relatively insensitive group controls for other simultaneous and spatially coincident shocks.

(i) In 1982, an unprecedented number of 66 terrorist attacks took place in Paris, a number never reached in subsequent years (see figure 6). Similarly, in Northern Ireland, recorded fatalities in the years 1975 and 1976 greatly outnumbered the fatalities of subsequent years (see figure 9). In order to investigate whether the negative correlation between terrorism and life satisfaction is largely driven by such observations, we repeatedly run the regressions reported in table 18 excluding in each round the observations for one region-year combination. For the United Kingdom and Ireland, the coefficient for the number of incidents varies between -6.2E-5 (t-value: -3.89) and -9.1E-5 (t-value: -4.98). Compared to the point estimate for the whole sample, the deviations are below ±20%. The coefficient for the number of fatalities varies between -5.0E-4 (t-value: -3.73) and -8.2E-4 (t-value: -3.86) or +22% and -28% compared to the whole sample. The coefficient for the number of incidents in France is less robust: it varies between -1.9E-3 (t-value: -3.32), a relative deviation of 14%, and -4.5E-3 (t-value: -2.98), a relative deviation of -105%. This lower bound is estimated if the observations for Paris in 1982 are excluded, i.e. the region and year with the highest number of attacks in France. The coefficient for the number of fatalities in France varies between -3.9E-3 (t-value: -1.83) and -6.0E-3 (t-value: -3.19), relative deviations of +30% and -20%. Except for the number of incidents in France and although there are clearly influential observations, the coeffi-

cients are thus relatively stable. All estimates of the effect of terrorism on life satisfaction are comfortably negative.

(ii) One might expect the negative correlation between terrorism and life satisfaction to be spurious because the state of the economy may be (negatively) correlated with the intensity of terrorist campaigns. If a high level of terrorist activity is accompanied by slackening of the economy, people may report lower life satisfaction because they fear job losses rather than terrorist attacks. Such a negative relationship between economic and terrorist activity is probable and can be due to two different causal processes. One the one hand, bad economic conditions and high levels of unemployment may facilitate the recruitment of rank and file activists. On the other hand, terrorism may dampen economic activity.

McKittrick and McVea (2001, p. 28) presume the first causal relationship for Northern Ireland when writing that "[i]t is scarcely a coincidence that some of the areas which featured prominently in the troubles […] were among those where […] high unemployment persisted." However, neither micro-level nor macro-level studies find evidence in support of this causal direction. Analyzing the characteristics of members of Israeli extremists, the Hezbollah, Hamas and Palestinian Islamic Jihad, Krueger and Maleckova (2003) and Berrebi (2003) find that poverty does not increase the propensity to participate in terrorism. If anything, terrorists, including suicide bombers, come from the ranks of the better off in society. Opinion polls conducted in the West Bank and Gaza strip find little evidence to suggest that deteriorating economy increases support for terrorism. Time-series analyses fail to find a significant relationship between terrorism and GDP growth in Israel (Berrebi 2003; Krueger and Maleckova 2003). For Spain, time-series data for the tourism industry and terrorism indicate that terrorism affects tourism, but not the reverse (Enders and Sandler 1991). Finally, according to cross-country studies, poverty does not increase terrorism risk as assessed by an international risk agency (Abadie 2006) or as reflected in the number of international terrorist attacks (Piazza 2006), nor do perpetrators predominantly stem from poor countries (Krueger and Laitin 2003). In sum, contrary to popular opinion, the preponderance of evidence suggests that there is no economic foundation for terrorism. Moreover, in the case of international terrorism, perpetrators mostly stem from abroad. Economic conditions in the target region are therefore unlikely to influence the amount of terrorism.

The other causal connection is better documented. Over the last few years, economic scholars have provided evidence for adverse effects of terrorism on various sectors of the economy and on overall economic activity (e.g. Abadie and Gardeazabal 2003; see Frey, Luechinger and Stutzer 2007 for a review). Panel data estimates of the determinants of investment and employment in the Northern Ireland manufacturing sector indicate that variations in the intensity of political conflict have a large and significant impact on economic activity (Fielding 2003). A 20% increase in the number of fatalities reduced investment in machinery and equipment by about 5.6% in equilibrium and construction investment by about 4.5%; the short-term reductions in investment to a one-period increase in the number of fatalities by one standard-deviation is well over 25%. The effects for employment are less pronounced and are sensitive to the data used.

In order to control for the potential simultaneity between high levels of political violence and the slackening of the economy and in order to see whether part of the negative effect of terrorism on life satisfaction works through contemporaneous effects on economic activity, we include the growth rate of GDP per capita and the unemployment rate as additional control variables in the micro-econometric life satisfaction functions. We are confident that these two variables are able to adequately capture the general economic situation; the need for data which are regionally disaggregated and date back several decades strongly restricts availability of further data. The data for France are only available since 1976. Table 19 presents the results.

Coefficients for both indicators of terrorism remain of similar magnitude and statistical significance when business cycle effects are controlled for. Most coefficients even slightly increase. In the case of the United Kingdom and Ireland, the coefficient for the number of incidents increases by 5%, the coefficient for the number of fatalities by 19%. In the case of France, the coefficient for the number of incidents increases by 9%, an increase of 3% is due to the change in the sample, an increase of 6% due to the inclusion of the macro-economic variables. The coefficient for the number of fatalities remains constant because the change due to the change in the sample and the change due to the inclusion of the macro-economic variables offset each other; the former amounts to -4%, the latter to +4%. Thus, neither does the course of the economy spuriously cause the negative correlation between terrorism and life satisfaction, nor are contemporaneous economic effects of terrorism an important channel through which terrorism affects life satisfaction.

*Table 19*. Robustness check: Effect of terrorism on life satisfaction controlling for macro-economic variables

| | U.K. and Ireland | | | | France | | | |
|---|---|---|---|---|---|---|---|---|
| *Dependent Variable* | I | | II | | III | | IV | |
| Life satisfaction | Coefficient | t-value | Coefficient | t-value | Coefficient | t-value | Coefficient | t-value |
| *Terrorism* | | | | | | | | |
| Incidents | -8.0E-5 ** | -4.49 | | | -2.4E-3 ** | -3.12 | | |
| Fatalities | | | -7.6E-4 ** | -4.07 | | | -5.0E-3 ** | -2.64 |
| *Macro-economic variables* | | | | | | | | |
| GDP per capita growth | 0.719 * | 2.01 | 0.791 * | 2.10 | 0.378 | 0.93 | 0.324 | 0.80 |
| Unemployment rate growth | -0.071 (*) | -1.71 | -0.073 (*) | -1.70 | -0.041 | -0.57 | -0.043 | -0.59 |
| *HH income* | | | | | | | | |
| ln(HH income) | 0.168 ** | 18.98 | 0.168 ** | 18.89 | 0.252 ** | 20.89 | 0.252 ** | 20.81 |
| HH size$^{1/2}$ | -0.094 ** | -7.97 | -0.093 ** | -7.87 | -0.163 ** | -12.23 | -0.163 ** | -12.18 |
| *Personal characteristics* | Yes | | Yes | | Yes | | Yes | |
| *Region specific effects* | Yes | | Yes | | Yes | | Yes | |
| *Year specific effects* | Yes | | Yes | | Yes | | Yes | |
| *Constant* | Yes | | Yes | | Yes | | Yes | |
| Number of observations | | 62,320 | | 62,320 | | 34,529 | | 34,529 |
| Number of clusters | | 75 | | 75 | | 70 | | 70 |
| Prob > F | | 0.000 | | 0.000 | | 0.000 | | 0.000 |
| $R^2$ | | 0.080 | | 0.080 | | 0.075 | | 0.075 |

*Notes*: (1) OLS estimates. (2) Standard errors are adjusted for clustering within regions per year. (3) ** is significant at the 99% level, * at the 95% level, and (*) at the 90% level.

The region-specific macro-economic variables have the expected effect on life satisfaction, but only in the sample for the British Isles in a statistically significant way.

(iii) We estimate differentiated effects of terrorism on life satisfaction for different sub-groups as an additional means to address potential simultaneity problems. If terrorism is found to affect different groups differently in a way that corresponds to prior expectations, this enhances our confidence that the estimated correlations are not caused by simultaneous and spatially coincident shocks. Unlike terrorism, these shocks have the same effect on all sub-groups. The problem with this approach is to find groups that are likely to suffer disproportionately from terrorism. Terrorist attacks kill people indiscriminately and unpredictably. Bombs exploding on the Paris metro or wrecking crowded pubs in Birmingham kill people from all walks of life. In Northern Ireland, people were killed randomly in so-called "doorstep killings" whereby victims were shot on answering the door. Even wider is the circle of the bereaved. Thus, although a majority of the victims of the Northern Ireland conflict were male and young (Fay, Morrissey and Smyth 1999, pp. 161-163), we do not find larger effects of terrorism for these groups, probably because they are under-represented among the bereaved.

We identify three sub-groups. First, we hypothesize that respondents living in rural areas are less affected than respondents living in towns and cities. Terrorists often strike in cities in order to increase the death toll and secure media attention. In Northern Ireland, some scholars distinguish a "rural war" from other types of conflicts. This war was fought between the protagonists themselves and resulted in a remarkably different profile of victims: "[…] a high proportion of casualties were members of the security forces who did not live in the area" (Fay, Morrissey and Smyth 1999, p. 143). Therefore, fear, empathy and grief are expected to be lower among rural residents. Second, social psychology suggests that religiousness plays an outstanding role in the list of factors that help to cope with the threat of terrorism (Peterson and Seligman 2003; Fischer et al. 2006). Hence, we expect self-reported agnostics and atheists to suffer more from terrorism. Finally, in the case of Northern Ireland, Catholics were at greater risk in both absolute and relative terms (Fay, Morrissey and Smyth 1999, p. 165). The results are reported in table 20. Because the information on the type of living area and religious denomination is not included in all waves of the EB, table 20 also contains the effect of terrorism on life satisfaction for the whole population in the respective sub-sample.

*Table 20*. Interaction effects: Effect of terrorism on life satisfaction for different groups

| *Dependent Variable* | U.K. and Ireland | | | | France | | | |
|---|---|---|---|---|---|---|---|---|
| Life satisfaction | I | II | III | IV | V | VI | VII | VIII |
| *Terrorism* | | | | | | | | |
| Incidents | -8.0E-5 ** | -9.8E-5 ** | | | -2.0E-3 * | -2.1E-3 * | | |
| | (-3.90) | (-4.05) | | | (-2.50) | (-2.51) | | |
| Fatalities | | | -6.9E-4 ** | -9.1E-4 ** | | | -4.7E-3 * | -5.0E-3 * |
| | | | (-3.45) | (-4.31) | | | (-2.26) | (-2.41) |
| *Sub-group of interest* | | | | | | | | |
| Living in rural area | 0.057 ** | 0.053 ** | 0.057 ** | 0.052 ** | 0.052 ** | 0.045 ** | 0.052 ** | 0.050 ** |
| | (9.37) | (8.28) | (9.38) | (8.11) | (7.54) | (4.73) | (7.56) | (5.84) |
| *Interaction terms* | | | | | | | | |
| Living in rural area · terror | | 3.8E-5 * | | 4.6E-4 * | | 1.9E-3 | | 1.9E-3 |
| | | (2.24) | | (2.48) | | (1.20) | | (0.75) |
| *HH income* | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| *Personal characteristics* | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| *Region specific effects* | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| *Year specific effects* | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| *Constant* | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Number of observations | 55,137 | 55,137 | 55,137 | 55,137 | 31,412 | 31,412 | 31,412 | 31,412 |
| Number of clusters | 63 | 63 | 63 | 63 | 61 | 61 | 61 | 61 |
| Prob > F | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| $R^2$ | 0.084 | 0.084 | 0.084 | 0.084 | 0.077 | 0.077 | 0.077 | 0.077 |
| Marginal effect of terror for | | | | | | | | |
| Reference group | | -9.8E-5 ** | | -9.1E-4 ** | | -2.1E-3 * | | -5.0E-3 * |
| Sub-group of interest | | -6.0E-5 ** | | -4.5E-4 * | | -2.2E-4 | | -3.1E-3 |

*To be continued.*

*Table 20*, part 2

| *Dependent Variable* | U.K. and Ireland | | | | France | | | |
|---|---|---|---|---|---|---|---|---|
| Life satisfaction | IX | X | XI | XII | XIII | XIV | XV | XVI |
| *Terrorism* | | | | | | | | |
| Incidents | -9.8E-5 ** | -9.8E-5 ** | | | -5.9E-3 * | -3.3E-3 | | |
| | (-3.88) | (-3.91) | | | (-2.42) | (-1.17) | | |
| Fatalities | | | -7.9E-04 ** | -7.9E-04 ** | | | -6.1E-03 | -2.0E-03 |
| | | | (-3.87) | (-3.89) | | | (-1.42) | (-0.45) |
| *Sub-group of interest* | | | | | | | | |
| Agnostic | -0.053 ** | -0.050 ** | -0.052 ** | -0.048 ** | -0.083 ** | -0.052 * | -0.083 ** | -0.072 ** |
| | (-6.09) | (-5.62) | (-5.92) | (-5.21) | (-4.48) | (-2.49) | (-4.48) | (-3.91) |
| *Interaction terms* | | | | | | | | |
| Agnostic · terror | | -4.0E-05 | | -4.2E-04 | | -7.6E-03 * | | -1.1E-02 (*) |
| | | (-1.04) | | (-0.79) | | (-2.50) | | (-1.77) |
| *HH income* | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| *Personal characteristics* | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| *Region specific effects* | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| *Year specific effects* | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| *Constant* | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Number of observations | 34,875 | 34,875 | 34,875 | 34,875 | 21,088 | 21,088 | 21,088 | 21,088 |
| Number of clusters | 45 | 45 | 45 | 45 | 47 | 47 | 47 | 47 |
| Prob > F | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. |
| $R^2$ | 0.084 | 0.084 | 0.083 | 0.083 | 0.075 | 0.076 | 0.075 | 0.075 |
| Marginal effect of terror for | | | | | | | | |
| Reference group | | -9.8E-05 ** | | -7.9E-04 ** | | -3.3E-03 | | -2.0E-03 |
| Sub-group of interest | | -1.4E-04 ** | | -1.2E-03 * | | -1.1E-02 ** | | -1.3E-02 (*) |

*To be continued.*

*Table 20*, part 3

| *Dependent Variable* | U.K. and Ireland | |
|---|---|---|
| Life satisfaction | XVII | XVIII |
| *Terrorism* | | |
| Incidents | -9.5E-5 ** | |
| | (-3.40) | |
| Fatalities | | -7.5E-04 ** |
| | | (-3.44) |
| *Sub-group of interest* | | |
| Catholic | -0.004 | 0.000 |
| | (-0.37) | (0.00) |
| *Interaction terms* | | |
| Catholic · terror | -1.3E-5 | -2.1E-4 |
| | (-0.74) | (-1.04) |
| *HH income* | Yes | Yes |
| *Personal characteristics* | Yes | Yes |
| *Region specific effects* | Yes | Yes |
| *Year specific effects* | Yes | Yes |
| *Constant* | Yes | Yes |
| Number of observations | 34,875 | 34,875 |
| Number of clusters | 45 | 45 |
| Prob > F | n.a. | n.a. |
| $R^2$ | 0.084 | 0.083 |
| Marginal effect of terror for | | |
| Reference group | -9.5E-05 ** | -7.5E-04 ** |
| Sub-group of interest | -1.1E-04 ** | -9.6E-04 ** |

*Notes*: (1) OLS estimates. (2) t-values are in parentheses. (3) Standard errors are adjusted for clustering within regions per year. (4) ** is significant at the 99% level, * at the 95% level, and (*) at the 90% level.

As can be seen from table 20, the estimates are consistent with the hypotheses. The effect of terrorism for people living in rural areas is only between one half and two thirds of the size of the effect for people living urban areas; for the number of incidents in France it vanishes almost entirely. According to all models, agnostics are more heavily affected by terrorism than their religious counterparts, in the United Kingdom and Ireland by a factor of 1.5, in France by a factor of 3.3 to 6.5. Finally, Catholics suffer more from political violence in the United Kingdom and Ireland, although the difference is less pronounced compared to the other differentiations.

5.4 Implicit willingness-to-pay

*WTP* estimates are presented for people living in regions prone to terrorism. Specifically, we calculate the hypothetical *WTP* for residents of Paris and Northern Ireland for a reduction in the number of incidents and the number of fatalities to bring them on a par with the rest of France (except for the region Provence-Alpes-Côte d'Azur) and the rest of Great Britain respectively. All *CS*s are calculated for an individual with the average annual household income. The results reported in table 21 are based on coefficients from least square estimations (table 18) and from ordered probit estimations.

*Table 21. WTP* estimates for a reduction in terrorism

| | U.K. and Ireland, 1975-1998 | | France, 1973-1998 | |
|---|---|---|---|---|
| *Average annual household income* | | $20,501 | | $26,067 |
| Reduction of terrorism | 1,022.76 acts | 77.04 deaths | 9.58 acts | 2.16 deaths |
| Basis: least square estimations (table 18) | | | | |
| Compensating surplus (*CS*) | $7,641 | $5,252 | $2,149 | $1,099 |
| | ($891) | ($892) | ($683) | ($413) |
| *CS* in percent of income | 37.3% | 25.6% | 8.2% | 4.2% |
| | (4.3%) | (4.4%) | (2.6%) | (1.6%) |
| Basis: ordered probit estimations | | | | |
| Compensating surplus (*CS*) | $7,877 | 5,454$ | $1,948 | $1,050 |
| | ($864) | ($ 918) | ($704) | ($437) |
| *CS* in percent of income | 38.4% | 26.6% | 7.5% | 4.0% |
| | (4.2%) | (4.5%) | (2.7%) | (1.7%) |

*Notes:* (1) *CS* is calculated for residents of Paris and of Northern Ireland for a reduction in the level of terrorism to level prevailing in the more peaceful parts of the respective countries. (2) *CS* estimates are in 2004 U.S. dollars. (3) Bootstrapped standard errors in parentheses (1000 replications).

According to the results shown in table 21, for a reduction in terrorist activity to a level that prevails in the more peaceful parts of the country, a resident of Northern Ireland would be willing to pay between 37% (if terrorism is measured by the number of incidents) and 26% (if terrorism is measured by the number of fatalities) of his or her income. A resident of Paris would be willing to forego between 8% (if terrorism is measured by the number of incidents) and 4% (number of fatalities) of his or her income. As can be seen from table 21, ordered probit estimations produce similar results; the respective numbers are 38%, 27%, 8% and 4%. Table 21 reports not only the point estimates but also the respective standard errors of the *CS* estimates. Standard errors are bootstrapped based on 1,000 repetitions taking into account that the *CS* is calculated based on the ratio of two estimated variables. According to the standard errors and the respective confidence intervals, we cannot reject that the two terrorism indicators, number of fatalities and number of incidents, generate the same results. For a resident of Northern Ireland, the 95% confidence interval of the *CS* for a reduction in the number of fatalities runs from 17% to 34%, the confidence interval for a reduction in the number of incidents from 29% to 46%. For France, the respective 95% confidence intervals are 1% to 7% and 3% to 13%. Hence, the *CS* estimates for France are significantly lower than the *CS* estimates for the British Isles.

We now put the main results for the *CS*s into perspective. The result for France, on the one hand, is comparable to the compensations which Blomquist, Berger and Hoehn (1988) identified on the labor and housing market in the United States for individuals living in the county with the highest rate of violent crime vis à vis individuals living in the county with the least crime. The compensation in Blomquist, Berger and Hoehn (1988) amounts to $2,267 (in 1980 U.S. dollars), or to 11% of the annual household income.

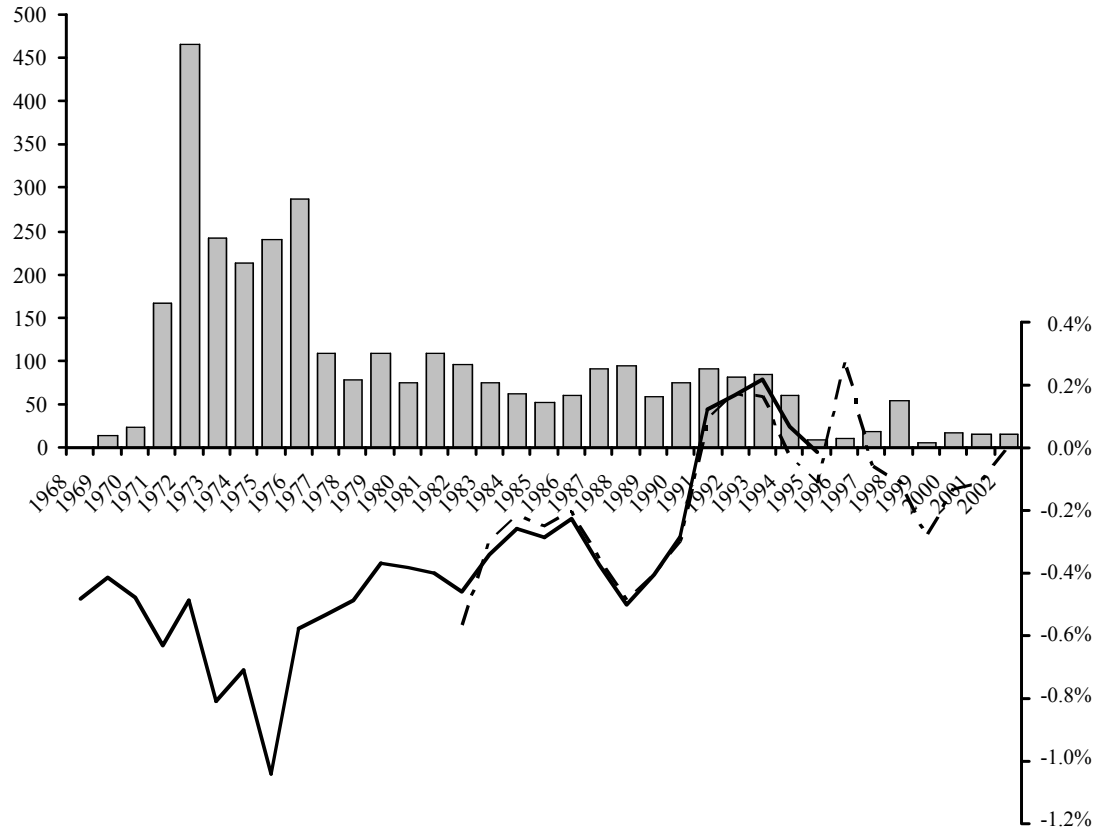
The result for Northern Ireland, on the other hand, reflects the ferocity of the conflict. The number of incidents and fatalities depicted in figure 8 and 9 gives a sense of this ferocity. Fay, Morrissey and Smyth (1999, p. 204) estimate that around two thirds of the Northern Irish population live in households where someone has been injured in a conflict related incident; the number of around 30,000 republican and loyalist ex-prisoners illustrates how deeply society was permeated by paramilitarism (McKittrick and McVea 2001, p. 150). In addition, curfews, rigorous house-to-house searches and large-scale riots accompanied the worst times of the conflict. The statements of two senior policemen summarize the situation: “The country

stared into the face of great difficulty and crept right to the edge of the abyss," and "We were on the brink of all-out civil war" (cited in McKittrick and McVea 2001, p. 211).

Given the ferocity of this conflict and our high estimate of a *CS*, one might wonder why no mass exodus out of Northern Ireland was observed. One reason might be that residents of Northern Ireland got indeed massively compensated for living in Northern Ireland: Without invoking a direct relationship to the figures presented in table 21, transfers from Great Britain to Northern Ireland (excluding defense and court expenditures) averaged one fourth of the Northern Irish GDP, or a third of income created in Northern Ireland itself, in the period considered. These subsidies support relatively well-paid jobs in manufacturing (over 90% of the manufacturing jobs are subsidized) and the public sector, and finance the health and welfare system as well as public housing (Fay, Morrissey and Smyth 1999, pp. 110-113). Thus, they directly benefit a large part of the population in Northern Ireland. Additional transfers to Northern Ireland take the form of expenditures for security and justice, and subsidies from the European Union. (With regard to the identification of utility losses caused by terrorism it is important to note that these transfers do not vary with the level of terrorist activity.) However, despite these enormous transfers, numerous people did leave Northern Ireland in reaction to the violence, as figure 10 suggests (see also Registrar General Northern Ireland various years).

Another reason for a high *CS* for lower terrorist activity might be people's difficulty in assessing risks of terrorism. According to Viscusi and Zeckhauser (2003), people are subject to a propensity to predict worst-case scenarios and are prone to anomalies known from other risk perception contexts. Hindsight bias and embeddedness effects are particularly evident for terrorism-risk perception. Downes-Le Guin and Hoffman (1993) contend that much higher probabilities are accorded to terrorism than to other life-threatening acts. Sunstein (2003), on the other hand, finds that individuals focus on the badness of the outcome rather than on the probability that it will occur. The "probability neglect" results in fear that greatly exceeds discounted harm. These results suggest that people are far more concerned with terrorism than with objectively larger risks. Becker and Rubinstein (2004) also assert that terrorism can have consequences beyond what the underlying probabilities would suggest. But rather than attributing this to cognitive limitations in risk assessing, they base their explanation on an additional "fear factor": An exogenous increase in risk not only affects utility by changing the probabilities but also by reducing the utility enjoyed from the consumption of risky activities such as

*Figure 10*. Fatalities in Northern Ireland and net migration (in % of population)




*Notes:* The Registrar General publishes two overlapping but not entirely consistent series of migration; both are shown in figure 10.
*Source:* Sutton (1994) and an updated version of the Sutton index provided by CAIN Web Service (www.cain.ulst.ac.uk ), and Registrar General (various years).

riding a bus after suicide attacks on buses. As Becker and Rubinstein (2004, p. 7) observe, "[b]y generating fear, terror, even in the form of a low probability event, may generate substantial effects." Calibrating a benchmark utility function to fit the data of Israeli bus demand and using commonly accepted values for the risk aversion parameter, they estimate the marginal utility of a bus ride to fall by 10 to 20 percent if suicide bomber attacks are carried out on buses. Thus, equating the terrorism with the probability of dying misses the distinctive feature of terrorism, i.e. to spread terror. Whether far-reaching consequences are explained by cognitive limitations or fear, perceptions of terrorism are mainly influenced by the salience of the topic. Intense media coverage of terrorist acts ensures that terrorism is present in people's minds. The high number of fatalities in violent periods of the conflict in Northern Ireland, for

example, means “that hardly a newspaper or evening television programme did not bring news of either a killing or a funeral” (McKittrick and McVea 2001, p. 94), and that “the local television news seemed to consist of nothing except more and more violence, the grieving bereaved, and threats of more to come” (McKittrick and McVea 2001, p. 194).

# 6. Conclusions

## 6.1 Conclusions for economics

The previous chapters have obvious implications for two research areas in economics, namely happiness research and non-market valuation. An open issue is whether the effects of public goods on life satisfaction should be monetized.

### 6.1.1 Happiness research

The determinants of subjective well-being can be usefully grouped along the two dimensions running from subjective to objective and from individual to collective. While most of the previous happiness research studied subjective-individual and objective-individual determinants, public goods and externalities clearly belong to the group of objective-collective determinants. Thus, the applications in the previous chapters strengthen earlier findings that it is worthwhile to extend the research in this area and to consider objective-collective determinants. Further, the applications and findings of the previous chapters also shed additional light on the nature of subjective well-being data. In chapter 2, we mentioned six requirements subjective well-being measures should meet. These requirements are important for empirical happiness research in general but, arguably, even more so for research on objective-collective determinants. The six requirements are (i) inclusiveness, (ii) reference to presence, (iii) sufficiently high signal-to-noise ratio, (iv) interpersonal (or intergroup) comparability, (v) cardinality and (vi) availability. Both the own applications and the applications reviewed in chapter 2 provide evidence on whether the subjective well-being measures are in compliance with the first three requirements. Before we discuss the evidence in more detail, two caveats are in order. First, though the evidence is indicative, the requirements are ultimately not verifiable. Second, although the applications add particularly convincing evidence, it is by no means the first evidence.

*Inclusiveness*. Public goods such as clean air and security are archetypical representatives of objective circumstances which psychologists often consider to be of low relevance for subjec-

tive well-being (e.g. Diener 1984).[32] The large effects of public goods documented in previous chapters contradict this view and suggest that subjective well-being, or at least life satisfaction, is a broad and inclusive concept. The notion that subjective well-being is an "exemplary narrow" (Adler and Posner 2006, p. 77) concept is clearly rebutted. The finding that environmentally conscious persons and risk groups suffer more from air pollution casts into doubt the hypothesis that health, sense of responsibility etc. are "higher order" goods or subutility functions of equal standing with subjective well-being (as asserted by Kimball and Willis 2006).

*Reference to presence and signal-to-noise ratio*. The negative effects of the public goods on life satisfaction are *prima facie* evidence that subjective well-being reflects, at least partly, current circumstances and that the signal-to-noise ratio is sufficiently high to make empirical research productive. The findings in the previous chapters show that the signal-to-noise ratio is high enough even to detect relatively small effects of external circumstances and not only the larger effects of demographic factors and personal characteristics. However, the results provide no evidence whether subjective well-being also reflects expected future utility and whether it is systematically biased in a way that interferes with estimating the coefficient of interest. These issues are important and require further research in the future.

### 6.1.2 Non-market valuation

Provided one accepts that subjective well-being is an adequate and valid approximation to utility, the data allow researchers to test the underlying assumptions of the standard non-market valuation techniques. For example, as explained in chapter 2, the negative relationship between life satisfaction and air pollution documented in chapter 3 indicates that air pollution is incompletely capitalized. Thus, the hedonic method understates the value of clean air. On the other hand, the close correspondence between the *WTP* estimates based on the life satisfaction approach and the estimates based on the hedonic method shown in chapter 4 invites to speculate that the problem of undercapitalization is more severe for externalities which are rapidly changing and which have important indirect effects than for stable and salient risks. However, the argument can be reversed. Provided that the underlying assumptions of the standard approaches hold, the negative relationship between life satisfaction and pollution indi-

[32] This position of psychologists is often based on the low proportion of variance explained by objective circumstances. However, the low proportion of variance explained only indicates that subjective well-being is either determined by additional factors or simply has substantial random disturbances.

cates that life satisfaction is not an adequate and valid approximation to utility. Yet, the former interpretation of the negative relationship between pollution and life satisfaction, i.e. the interpretation of the negative relationship as an indication for incomplete capitalization of pollution in the housing market, is also supported by the behavioral evidence mentioned in chapter 2.

It was the aim of the previous chapters to convince the reader that subjective well-being data can be used to value public goods and, hence, that the life satisfaction approach expands the economists' toolbox in the area of non-market valuation. In chapter 2, we discussed specific advantages of the life satisfaction approach over the traditional methods. This discussion is not repeated here. On a meta-level, the life satisfaction approach differs from the standard approaches along two dimensions. First, the life satisfaction approach is based on survey data while most standard approaches are based on behavioral data (an exception is the contingent valuation method). Second, the life satisfaction approach captures experienced utility, the standard approaches decision utility. Although some aspects of these dimensions are discussed in chapter 2, the two dimensions deserve some further consideration to assess the main merits, but also limitations, of the life satisfaction approach.

*Survey versus behavioral data*. While for early economists introspection and communication were legitimate sources of data (Bruni and Sugden 2007), the positivistic movement in the social sciences instilled a deep suspicion of survey data in economists. Most economists subscribe to the standard behaviorist argument that subjective experience has no role in scientific analysis because it is not publicly observable (Sen 1982, p. 9; Kahneman and Varey 1991, p. 129). According to Sen (1986, p. 18), "[t]he popularity of this view in economics may be due to a mixture of an obsessive concern with observability and a peculiar belief that choice (in particular, market choice) is the only human aspect that can be observed." This distrust of survey data is based on two, somewhat contradictory, arguments (e.g. Bertrand and Mullainathan 2001). On the one hand, respondents are seen as "cognitive misers" (a term coined by Fiske and Taylor 1984) that make little mental effort in answering survey questions. Therefore, survey questions are unduly influenced by all sorts of contextual factors and the like. On the other hand, respondents are believed to anticipate all the consequences of their answers and strategically adjust their answering behavior so as to maximize their expected benefits from answering the question. Because market choices have consequences which lead individuals to internalize the benefits of incremental cognitive efforts and also part of the costs of strategic be-

havior, they are perceived as more reliable. This view is reflected, for example, in the guidelines of the Office of Management and Budget (OMB) of the White House: "Other things equal, you should prefer revealed preference data over stated preference data because revealed preference data are based on actual decisions, where market participants enjoy or suffer the consequences of their decisions" (OMB 2003, p. 24).

For several reasons, this reliable behavioral data versus unreliable survey data dichotomy is too simplistic. First, experimental findings show that people behave similarly in low- and in high-stake situations (e.g. Hoffman, E., McCabe and Smith 1996; Fehr, Fischbacher and Tougareva 2002; for contrary evidence, see the references in Levitt and List 2007). Second, there also is a possibility of strategic non-verbal choice behavior (Sen 1982, p. 9). Third, in order to interpret behavior, strong assumptions are necessary, assumptions which have been repeatedly falsified (e.g. Kahneman and Tversky 1979, the *locus classicus* for deviations from the expected utility theory, or Fair and Jaffee 1972 and Rosen and Quandt 1978 for empirical studies on disequilibria in the housing and labor markets). Fourth, the relevant behavior is often unobservable. Finally, critics fail to differentiate between different types of survey data. While the concerns are valid in principle, their importance is not independent of the question asked. As discussed at length in chapter 2, we suggest both problems to be less severe in the case of the life satisfaction approach compared to contingent valuation surveys. Overall, economists have been prone to overstate difficulties of survey data and underestimate the problem associated with behavioral data (Sen 1982, p. 72). Instead of rejecting one source of data in its entirety and uncritically embrace the other source, the relevant question should be what type of survey data or behavioral data is adequate for which questions.

*Experience versus decision utility*. The second difference between the standard approaches and the life satisfaction approach on a meta-level is that the former capture decision utility while the latter captures experienced utility. In revealed preference theory, the two concepts are equated as a matter of definition. The rationality assumption, with consistent and stable preferences, precludes divergence between experience and decision utility. Thus, preferences and utility can be interpreted as constructs summarizing choice in formal analysis and, simultaneously, as welfare measures in informal discussion and welfare statements (for a critical dis-

cussion, see e.g. Sen 1982, pp. 54-73; Kahneman and Sugden 2005; Camerer 2006).[33] In chapter 2, we took side with the view prevalent in behavioral economics that experience and decision utility diverge and that only the former is an adequate measure of individual welfare. Two considerations motivate this position. First, it is reasonable to assume that people try to maximize experienced utility (Kahneman and Thaler 1991) and that they would change decisions that are inferior in this respect were it not for limited cognitive abilities, ignorance and a lack of willpower (Thaler and Sunstein 2003). Second, if people are boundedly rational, no coherent preferences are revealed and no measure of decision utility exists (Kahneman and Sugden 2005). Thus, there are good reasons to favor experience over decision utility. However, in the context of policy evaluation and decision making, this position needs to be qualified. If a decision regarding the adequate level of public good provision is based on measures of experienced utility rather than measures of decision utility, the decision may amount to paternalism, in fact, to paternalism in its textbook form (e.g. Dworking, G. 2005) and not to paternalism in its less intrusive 'libertarian' (Thaler and Sunstein 2003) or 'asymmetric' (Camerer et al. 2003) form. Such a decision may also result in offsetting behavior (Peltzman 1975; Viscusi and Aldy 2003). Therefore, it is important to identify what drives the wedge between the value for public goods revealed in actual and stated choices and the value reflected in measures of experienced utility.

A first cause for this wedge are positional concerns. While income may be a positional good, valued in terms of relative position, public goods are likely to be non-positional goods that are valued for their own sake. If individuals act in isolation and buy public goods in the housing and labor markets, they experience not only an absolute but also a relative decline in disposable income. Therefore, the hedonic method understates the value of a change in public good provision if that change leaves the original income distribution intact (Frank 2000; Frank and Sunstein 2001; see also Kniesner and Viscusi 2003 arguing against the relevance of positional concerns in the area of non-market valuation). Second, hyperbolic discounting is a problem for traditional methods if intertemporal choices are involved, e.g. if individuals in contingent val-

[33] Sumner (1996, p. 122) accuses economists that they "trade on the ambiguity latent in the notion of preference." Similarly, Sen (1982, p. 94) criticizes that traditional economic theory and welfare economics relies on the identity of choice and welfare, an identity "obscured by the ambiguity of the term 'preference' […]." Welfare economists aware of this problematic dual link propose to base welfare economic entirely on a choice-theoretic approach (Bernheim and Rangel 2007) and view welfare economics as a part of positive economics with no normative content (Gul and Pesendorfer 2007).

uation surveys have to decide on immediate costs of regulations with delayed environmental benefits or if individuals trade off current income for future health benefits. In a stated preference (conjoint) survey on *WTP* for improvements in water quality, Viscusi and Huber (2006) find indeed a pattern of discount factors that is consistent with hyperbolic discounting (see also Cropper and Laibson 1999 for implications of hyperbolic discounting on project evaluation). Third, as discussed in chapter 3, the standard approaches understate experienced utility derived from public goods if adaptation to income is faster and/or more complete than adaptation to public goods and if adaptation is not anticipated or underestimated. Finally, there are several other factors which are also mentioned in chapter 2 such as ignorance, incorrect intuitive theories on the determinants of happiness and focusing illusion.

Whether a decision is potentially perceived as paternalistic and induces offsetting behavior depends on the cause of the wedge between experience and decision utility. On the one hand, if positional concerns are important and people knowingly suffer from self-control problems, a decision that is justified solely on the basis of experienced utility will not be perceived as paternalistic and induce no offsetting behavior. In contrast, such policies may be welcomed as a means to mitigate the negative consequences of consumption externalities and self-control problems (this is similar to the idea expressed in Frey and Eichenberger 1994 that individuals have an incentive to avoid decision anomalies trough individual or collective actions). All other causes, on the other hand, have to do with a lack of information. Individuals are ignorant about the degree or rate of adaptation, the level or effects of public goods, the falsity of their intuitive theories etc. Hence, the crucial question becomes how fast individuals learn once the decision has been taken. If they learn quickly, they will probably not perceive the decision as paternalistic and no offsetting behavior will occur. However, from a politico-economic perspective, such a decision will be difficult to implement. If the individuals learn only slowly or not at all, a decision based on measures of experienced utility is also problematic from a normative perspective.

One might wish to read a more unambiguous verdict in favor of one approach or the other in the concluding remarks. However, we are confident that the discussion of the two major differences between the life satisfaction approach and the standard non-market valuation techniques as well as the more practical issues presented in chapter 2 help to decide which approach or which combination of approaches is adequate in a particular situation.

### 6.1.3 Open issue: Monetization

The standard argument for monetization of externalities and public goods is that money is a convenient measuring rod that allows decision makers to compare various benefits and costs. For example, Fullerton and Stavins (1998, p. 438) suggestively ask: "How else can we combine the benefits of ten extra miles of visibility plus some amount of reduced morbidity, and then compare these total benefits with the total cost of installing scrubbers to clean stack gases at coal-fired power plants?" However, it has long been recognized that *WTP* for a change in public good provision is an imperfect approximation for the effects of the change of overall welfare because of the wealth effects and the variable marginal utility of income or, in other words, because of the diminishing marginal utility of income. Suppose, for example, that a public project benefits the poor but hurts the rich. Such a project may increase aggregate welfare even though the sum of individual *WTP* is negative. Therefore, several authors suggest to use distributional weights (e.g. Layard and Walters 1994; Sunstein 2007). Further, if public goods are monetized with the life satisfaction approach, estimates on the effect of income on life satisfaction play a crucial role. Unfortunately, as explained in chapter 3, estimating the effect of income on life satisfaction is associated with serious problems, most importantly endogeneity and omitted variable problems. Therefore, it seems natural to ask whether monetization is necessary at all. The conceptual and practical difficulties in connection with monetization may well speak in favor of subjective well-being scores as an alternative non-monetary scale.

Without taking side, several counterarguments speak in favor of monetization. First, comparing the costs and benefits of a project directly in life satisfaction terms may be advantageous if both costs and benefits accrue in non-monetary form. For example, if the major cost of a proposed environmental regulation is an increase in unemployment, the life satisfaction consequences of an increase in unemployment can be compared to the life satisfaction consequences

of the environmental improvement.[34] However, if costs naturally accrue in monetary form, e.g. if compliance costs decrease firms' profits and increase consumer prices, these costs have to be converted into life satisfaction scores. Converting monetary figures into life satisfaction scores is associated with exactly the same potential problems as the reverse operation. A second and related concern is that in many situations, the life satisfaction approach is complementary to the standard techniques and captures the residual shadow benefits only (see chapter 2). In these situations, *WTP* estimates based on different methods have to be summed-up in order to calculate the total shadow benefits of a public good. Again, therefore, either the effects on life satisfaction monetized have to be monetized or the monetary *WTP* estimates have to be translated into life satisfaction terms. Third, for some potential uses of the life satisfaction approach, welfare effects ultimately have to be expressed in monetary terms. An example are tort cases. Tort law serves two purposes. It aims at compensating the plaintiffs ("making the plaintiffs whole") and at deterring torts. For both purposes, it is necessary to assess the consequences of the tortfeasors' behavior on plaintiffs' utility and translate these consequences into a monetary fine (see e.g. Posner and Sunstein 2005). Fourth, a large body of literature exists that contains a wealth of information on people's *WTP* for public goods. For academic curiosity and for practical purposes, one might want to compare estimates based on the life satisfaction approach to these *WTP* estimates. For example, in conducting cost benefit analyses, agencies often make no original benefit assessment but revert to existing studies. Non-monetized estimates based on the life satisfaction approach are of little use in this context. Experience shows that non-monetized costs or benefits included in cost benefit analyses are usually not considered in addition to the monetized effects, but rather not at all (Viscusi 2006). Of course, for comparative purposes, the more often the life satisfaction approach is applied and, hence, the more public goods are valued in life satisfaction terms, the less important monetization becomes. However, as Adler (2006, p. 1968) reckons, building up an ade-

[34] The "environment versus jobs" trade-off routinely features in public debates on environmental policy. In a 1990 poll conducted by the Wall Street Journal, 33% of respondents thought it was likely or somewhat likely that their own job was threatened by environmental regulation (Rosewicz 1990). Before air quality regulations are tightened, business leaders often predict massive layoffs as a consequence of the regulation (see e.g. Hahn and Steger 1990). Retrospective analyses by economists paint a less gloomy picture. Gollop and Roberts (1983) estimate that air quality regulations increases labor demand for fossil-fueled power generation (though it decreases productivity), and Morgenstern, Pizer and Shih (2002) find no significant change in employment for four other heavily polluting industries. Nevertheless, at the regional level, the trade-off can be relevant. Several studies find negative employment effects in U.S. counties that did not meet federal air quality standards and that are therefore subject to stricter regulations, such as lower growth rates in manufacturing employment (Henderson 1996), increased rates of plant shutdowns and lower rates of plant births (Becker, R. and Henderson 2000) and substantial job losses (Greenstone 2002).

quate stock of information takes time: “In two or three generations, perhaps, welfarist policy analysis might dispense with money as its commensurating device and express costs and benefits in terms of interpersonal utility units. But – given the huge amount of information about money values provided by behavioral data as well as existing CV [contingent valuation] studies, and the absence of a comparable body of interpersonal utility information – that prospect seems distant.”

## 6.2 Conclusions for policy

In the following, we discuss the policy implications of the estimates reported in previous chapters. But in order to realistically appreciate what role such estimates can play in the political process, it is first necessary to briefly discuss the role of cost benefit analysis and benefit assessment more generally.

### 6.2.1 Preliminary note: The role of cost benefit analysis

To assess the role that cost benefit analysis can play in the political process, it is useful to distinguish between two perspectives on the political process, namely the social planner or benevolent dictator model versus the public choice view.

In the social planner model, cost benefit analysis has a clear and strong place (Hettich and Winer 1993; Becker, G. S. 2000). The benevolent dictator view reverberates in the proposals of Supreme Court Justice Breyer (1993) and Sunstein (2002a, b; 2005) for more rational regulations. They attribute regulatory inconsistencies to an undue influence of the public’s ill-founded fears and blunders on elected officials. Therefore, they demand more responsibilities for politically insulated expert agencies. These expert agencies would largely rely on cost benefit analysis as a corrective for the cognitive limitations of citizens. The proposals are a “plea for a strong role for technocrats” (Sunstein 2002b, p. 151) and meant to harness “the inherent virtues of civil service” (Breyer 1993, p. 67). Of course, regulators who are insulated from the scrutiny from elected officials and the public may further their own agenda and be more vulnerable to regulatory capture (Pollak 1998). These, however, are concerns from a public choice perspective to which we now turn.

According to the public choice theory, politicians and civil servants lack information and incentives to make regulatory decisions in the public interest (e.g. Frey 1978; Mueller 2003). Evidently, cost benefit analysis can help to overcome the informational problem, but its influence depends on the incentive structure and its effect thereon.[35] In the following, we discuss how cost benefit analysis can affect policy outcomes if it is conducted by (i) the government, (ii) the regulatory agencies or (iii) the courts.

*Government*. In representative democracies, the most important constraint on the behavior of an incumbent government is the need to be re-elected. The political competition and the re-election constraint give incumbent governments and their challengers in the opposition an incentive to acquire information on citizens' preferences (Pommerehne 1987, p. 4).[36] Politically defined costs and benefits often differ from economically defined ones, but cost benefit analysis nevertheless provides a great deal of politically pertinent information (see Hettich 1983 for a case study of Canadian cost benefit analyses). Even if policy outcomes are mainly determined by the relative strength of lobbying by interest groups, projects with larger net benefits are more likely to be adopted. This is because the more a project's benefits outweigh its costs, the larger will be the difference in political spending by supporters compared to opponents *ceteris paribus* (Becker, G. S. 2000). In addition to the re-election constraint, other possible constraints on politicians' behavior are direct democratic participation rights (e.g. Kirchgässner, Feld and Savoiz 1999; Frey and Stutzer 2006) and auditing committees, especially if they have the authority to make counter-proposals (Eichenberger and Schelker 2007). These institutions make specific policies subject to public approval and give outsiders agenda setting power. Because the government probably does not like to see its policy proposals rejected in a referendum or to lose to a counter-proposal of the auditing committee, it has additional incentives to be informed. Similarly, initiatives and counter-proposals have a better chance to be accepted if they are tailored to the preferences of the voters. Information on the

[35] Missing incentives of politicians to further the general welfare are also an important argument against the proposal of developing National Well-Being Indicators and the implied obligation of politicians to maximize aggregate happiness (Frey and Stutzer 2007).

[36] Electoral incentives seem to play an important role even for secondary policy issues such as environmental regulation. In contrast to the popular view that secondary policies are largely determined by lobbying, empirical results of List and Sturm (2006) suggest that there are strong effects of electoral incentives. Using panel data on environmental policy choices in the U.S. states, they find that environmental policy differs considerably between years in which the incumbent governor can be re-elected and years in which he faces a binding term limit. The direction and magnitude of the difference is determined by the voters' preferences and the degree of political competition.

benefits of a proposal may also be an important argument in a referendum campaign. Thus, both institutions increase political competition and may, thereby, well increase the demand for cost benefit analysis (see Frey and Oberholzer-Gee 1998 on cost benefit analysis and direct democracy).

*Regulatory agencies*. Both in practice and in the academic literature, cost benefit analyses conducted by regulatory agencies play the most important role. In the United States, presidential executive orders require cost benefit analysis of all major regulations (where this is statutorily permissible) and give the OMB the power to review regulations and related cost benefit analyses of the responsible agency. The OMB reviews a large number of rules and also increasingly changes the rules (see Croley 2003). Courts frequently mandate cost-benefit analyses, asking agencies to monetize costs and benefits. Thus, as a default the executive and judiciary require agencies to perform cost benefit analyses unless the Congress expressly precludes it (Sunstein 2002a, b).[37] In some European countries, for example in the United Kingdom, a central unit performs regulatory impact assessment including cost benefit analyses. In others, for example in Germany, oversight is fragmented and relatively autonomous agencies perform their own cost benefit analyses (Hahn and Litan 2005). In Switzerland, the Bundesrat (federal government) can commission agencies to conduct a cost benefit analysis; most costs benefit analyses are related to transport (Maibach and Peter 2000; Walter et al. 2000; Werder 2000). Thus, in all countries, cost benefit analyses are mostly conducted by agencies on behalf of the government.

This role of cost benefit analysis in the regulatory reality has inspired theoretical models that see cost benefit analysis mainly as a device of elected officials to monitor and discipline agencies (e.g. Posner 2001; Johnston 2002; Adler and Posner 2006). In Posner's (2001) model, for example, an interventionist agency with an informational advantage can make a take-it-or-leave-it regulatory proposal to the government. Without cost benefit analysis, the government can only infer the pre-regulatory state of the world from the proposed regulation and the agencies ideal point on the policy dimension. In some situations, the agency has to propose excessive regulation (even from its own perspective) in order to convince the government of the

[37] Cost benefit analysis is so firmly established in the U.S. regulatory process that Sunstein (2002a, p. xi; 2002b, pp. 5-6) speaks of a victory for the advocates of cost benefit analysis in the "first generation" debate on whether cost benefit analysis should play a role. The "second generation" debate now concentrates on the appropriate method for valuing costs and benefits.

necessity of regulation. In other words, the informational asymmetry precludes mutually beneficial regulatory proposals. In this situation, cost benefit analysis can play an important role. This is even true if the cost benefit analysis can be manipulated. The only condition is that the costlier it is to fake a plausible analysis, the less efficient the proposal is. In such a situation, cost benefit analysis has two effects. First, the agency can convince the government of the necessity of regulation by conducting an expensive cost benefit analysis rather than by proposing excessive regulation. Second, in order to preserve funds for other projects rather than wasting them on costly cost benefit analyses, the agency has an incentive to issue efficient regulations.[38] Although it is possible to criticize various aspects of Posner's (2001) model, it illustrates that cost benefit analysis can improve regulations even if the regulators have their own agenda and the cost benefit analysis is not the decisive decision criterion. Most likely, cost benefit analysis will increase transparency of agency decision making and, thereby, facilitate oversight by elected officials and the public. For some authors, this transparency-enhancing effect of cost benefit analysis restricts the informational advantage and thus the influence of interest groups (e.g. Becker, G. S. 2000; Adler and Posner 2006). For others, cost benefit analysis is likely to increase interest group influence because it is an additional forum for interest groups to block regulations.

*Courts*. In two different contexts, cost benefit analysis and benefit assessment become important for courts. First, in some countries (e.g. in the United States) courts can review regulations issued by government agencies. In this context, courts do usually not conduct their own cost benefit analysis but vacate regulations if the agency's analysis is seriously flawed. In this way, the courts increase the consistency and quality of agencies' cost benefit analyses (Sunstein 2002b, pp. 181, 191-228; Adler and Posner 2006, pp. 111-114). Second, benefit assessment is of direct relevance in courts if externalities are controlled by means of liability rules (Calabresi 1970; see also White and Wittman 1983; Kolstad, Ulen and Johnson 1990 on the relationship between regulation and liability rules). In the United States, the standard non-market valuation methods such as the contingent valuation method, the hedonic method and the travel cost approach have been used in various legal cases (Thompson 2002). For example, in the Exxon

[38] The costs of conducting a cost benefit analysis and a proper benefit assessment are not trivial. Morgenstern and Landy (1997) estimate the average costs of preparing a cost benefit analysis for OMB review to lie in the vicinity of between $1 million and $2 million. An astonishing amount of between $8 million and $10 million was spent on the contingent valuation survey assessing the non-use values lost due to the Exxon Valdez oil spill (Thompson 2002) (all amounts are in U.S. dollars; year not known).

Valdez oil spill litigation, the contingent valuation method has been used to assess the non-use values for determining punitive damages and the hedonic method has been used for damage assessment to native Alaskans subsistence use of fish and wildlife (Duffield 1997; Carson et al. 2003).

Therefore, although the role of cost benefit analysis is less clear if the political process is seen trough the lenses of the public choice approach rather than the social planner model, it is still a useful framework for consistently organizing disparate information and thereby improving the political process and the resulting policies (Arrow et al. 1996).

### 6.2.2 Policy implications

Keeping in mind the potential role of cost benefit analysis outlined in the previous section, the estimates presented in chapters 3 through 5 can serve as benefit estimates in cost benefit analysis. The estimates can be used to retrospectively evaluate policies such as the large combustion plant ordinance or to assess the welfare gains from the pacification of Northern Ireland. The estimates may also contain useful information for prospective evaluation of policies and priority setting. For example, the estimates on the effect of flood disasters may guide the U.S. Army Corps of Engineers that is instructed by one of the oldest laws mandating cost benefit analysis to undertake a project useful for "flood control purposes if the benefits to whomsoever they may accrue are in excess of the estimated costs" (U.S. Flood Control Act of 1936, §1).

For all public bads analyzed in the previous chapters, we find large negative effects on life satisfaction that translate into considerable *WTP* estimates for a reduction in the exposure to these bads. This suggests that the improvement in air quality in Germany documented in chapter 3 and the peace process in Northern Ireland with the associated decline in violence, recently consolidated trough the power sharing deal between Sinn Fein and Paisley's Democratic Unionist Party (Economist 2007a), brought about tremendous welfare gains. The large combustion plant ordinance in Germany belongs to the heave-handed and costly command-and-control regulations. Nevertheless, though no reliable estimates of the social costs of the ordinance are available, its benefits are likely to outweigh its costs by a safe margin (see chapter 3). More tentatively, the findings suggest that it may be worthwhile to curb other pollutants (e.g. $NO_2$ and TSP) and air pollution in other countries (e.g. in Russia and China with

$SO_2$ concentrations in urban areas in the mid-nineties of around 100 $\mu g/m^3$; see Yale Center for Environmental Law and Policy 2002) or to counter terrorist activities in various parts of the world. Of course, the larger the differences in the attributes of the public goods, in the populations enjoying the benefits or in the contexts within which the goods are provided become, the more problematic a one-to-one transfer of benefit estimates will be (these issues are acknowledged and discussed in the literature on benefit transfer; see e.g. Boyle and Bergstrom 1992; Ready and Navrud 2005). Nevertheless, some generalizations can be safely drawn. First, whatever the exact *WTP* for clean air, it is larger than previously thought. Thus, regulatory proposals rejected on the basis of a small benefit-cost ratio may be worth reconsidering. Second, at least in the developed countries of the West, the major losses from flood disasters are insurable material costs and only to a lesser extent non-insurable psychic costs. Third, terrorism has far larger repercussions than what the bare mortality risk would imply. Therefore, there are reasons to treat different mortality risks differently and allow for discrepancies in the costs per life saved in the area of health and safety regulations as well as security.

The size of the benefits tells us nothing about the means by which the public good should be provided. In the case of air quality, a heavier reliance on incentive-based mechanisms could increase the positive net effect of regulations even more. Economists have argued for a long time that incentive-based instruments such as tradable permits, pollution charges and government subsidy reductions are more efficient and have lower compliance costs (e.g. Baumol and Oates 1975; for an empirical analysis, see e.g. Schmalensee 1998). Similarly, flood disasters can be prevented by active measures such as technical defense works or by passive measures such as hazard zone maps (Steininger and Weck-Hannemann 2002). Alternatively, the effects of flood disasters can be mitigated through construction standards (e.g. Lave and Apt 2006) or risk transfer mechanisms. Regarding the latter, mandatory insurance systems or public-private partnerships that overcome failures in the market for hazard insurance are generally preferable to government disaster relief, be it ad-hoc transfers or institutionalized disaster relief programs (Kunreuther 1996; Kunreuther and Pauly 2006; Raschky and Weck-Hannemann 2007). Also in the case of terrorism, possibly superior alternatives to the widely used deterrence policy are available. For example, terrorist activity may be reduced by lowering the benefits of terrorism to prospective terrorists or by increasing the opportunity costs of terrorism through positive incentives (e.g. Frey and Luechinger 2003; 2004; Frey 2004). In all three areas, there is a mod-

erate increase in the use of the preferred policy instruments. This tendency is most pronounced in environmental regulation (e.g. Hahn 2000; Stavins 2003; Stavins and Revesz 2007). Yet even in counter-terrorism policies, it is possible to find hesitant attempts to use positive incentives (see e.g. Derichsweiler 2007; Frey and Luechinger 2007; Gaupp 2007). Nevertheless, politico-economic considerations suggest that such alternative policies will resist widespread use (e.g. Frey 1972; Kirchgässner and Schneider 2003; Weck-Hannemann 2003 on environmental policies; Steininger and Weck-Hannemann 2002; Raschky and Weck-Hannemann 2007 on natural hazard policies; Frey and Luechinger 2003 on counter-terrorism policies).

## 6.3 Prospects for future research

There are two areas that warrant further research in the future. First, important insights will be gained by additional comparisons of the life satisfaction approach with the standard methods. On the one hand, such comparisons will improve non-market valuation. We have singled out one fruitful confrontation between the life satisfaction approach and one of the standard methods for an in-depth analysis, namely the comparison with the hedonic method. However, life satisfaction data could also be used to test the underlying assumptions of other non-market valuation techniques, to assess the utility consequences of individuals' behavioral responses to changes in the public good provision, or to estimate the residual shadow costs that are not captured by the standard methods. For example, subjective well-being data would allow us to test the crucial assumption of the travel cost approach that traveling to a recreational site provides no direct utility or disutility. Or, they could be used to quantify the non-pecuniary costs of defense behavior that is relevant for the defense expenditure approach. On the other hand, comparisons of the life satisfaction approach with the standard approaches will inform economics more generally. For example, they will allow us to derive conditions under which the gap between experience and decision utility is likely to be large and conditions under which the gap is likely to be small.

The second area for future research relates to improvements of the life satisfaction approach. One major issue in this respect is a need for better estimates of the effect of income on life satisfaction. So far, estimates based on exogenous changes in income are rare. This issue also points to a more general aspect. Happiness research has begun to take economics more seriously. After an early phase in which partial correlations have been interpreted in a

straightforward and direct manner as the effect of one variable on another, researchers increasingly realize that many correlates are actually choice variables (e.g. Frey and Stutzer 2004b for commuting). As we all know, choices involve trade-offs. Thus, it should strike no economist by surprise if – at least at the margin – the raw effect of the choice variable on life satisfaction is small. Another issue concerns the subjective well-being measures. We argued that existing measures of subjective well-being, particularly global self-reports, are well suited for the purpose of valuing public goods. Yet there is still the concern that these measures and the estimates based thereon are systematically biased because of conceptual problems and contextual factors such as question order effects and the lack of cardinal, intergroup comparability. The life satisfaction approach would greatly benefit if these problems were taken seriously in the development of the next generation of subjective well-being measures.

In all, therefore, there is still room for improvement and many of the questions raised in this thesis remain unanswered. However, if we convinced the reader that subjective well-being data can be potentially used to value public goods and that it is worthwhile to address the open issues, we have achieved our aim.

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**Curriculum Vitae**

Simon Lüchinger was born in Zurich, Switzerland, on July 5, 1975. He attended the Freie Gymnasium Zürich and graduated in 1996 (Matura Typus E). From 1996 to 2003, he studied history, economics and political science at the University of Zurich. In 2003, he graduated *summa cum laude*. From 2003 to 2007, he was a doctoral student in economics at the University of Zurich. In 2007, he graduated *summa cum laude*. From 2002 to 2006, he was a research assistant to Prof. Dr. Bruno S. Frey at the Institute of Empirical Research in Economics at the University of Zurich. Since 2006, he is a research assistant to Prof. Dr. Gérard Hertig at the ETH-Zurich (Swiss Federal Institute of Technology).